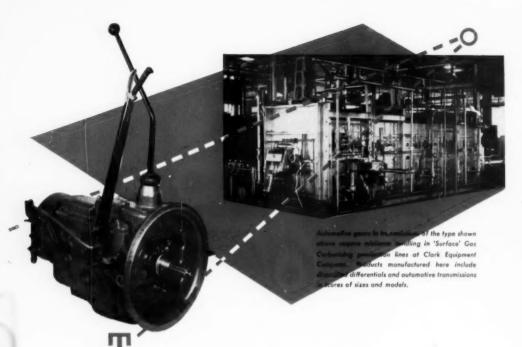
Metal PROGRESS



SEPTEMBER 1951



I ransmission Parts are Gas Carburized in a 'Surface' Continuous Furnace...on a job-shop basis!

Practically all major transmission manufacturers heat treat their component parts in 'Surface' furnaces. Why? Take the Clark Equipment Company, Jackson, Michigan, as an example.

Despite variations in size, shape and metal of parts to be treated, Clark engineers wanted heat treat equipment that afforded flexibility on a job-shop basis, with close control, minimum rejects, dependability, economy, and lasting stamina.

Today, by carburizing 14 component parts in either of two 'Surface' 3-row tray-pusher type, Radiant Tube furnaces with RX gas atmosphere, Clark Equipment Company produces rugged, durable automotive transmissions.

Gears and mainshafts of Clark transmissions are made of fine grain alloy steel (8620) and carburized to the case depth specification of .035"-.050" at a temperature of 1675 F. They are then quenched direct into 170-180 F. oil, washed, and tempered at 325 F. for one hour at temperature. Furnaces afford a total capacity of 1500 lb/hr., near elimination of distortion and a high degree of uniformity within very rigid manufacturer's specifications.

This example is typical of the extreme flexibility of production line operations possible with 'Surface' furnaces. Ask your 'Surface' engineer for more details or write for bulletins covering heat treatments of interest to you.



SURFACE COMBUSTION CORPORATION, TOLEDO 1, OHIO



...using THERMALLOY* trays and grids for carburizing application

Average Cost per Heat/Hour	
.0048	6707
.0095	3443
.0092	3022
	.00956

(Note: Figures do not include trays damaged in furnace wrecks, by rough handling, etc.)

The trays and grids shown above are used for carburizing automotive gears at a temperature of 1650° F. Through the use of Thermalloy "50", plus certain design changes, average cost per heat/hour has been cut in half...average hours of service life more than doubled. (See figures at left.)

This is one of many cases where customers have greatly benefited from Thermalloy's heat-resistant properties . . . plus the ability of Electro-Alloys engineers to develop designs suited to ideal foundry practice as well as to customer service requirements.

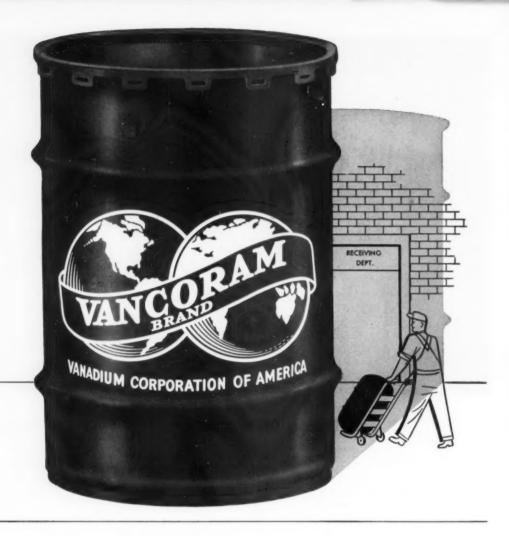
Thermalloy is not just one alloy, but a group of alloys ... each specially adapted to certain heat and abrasion requirements. Our engineers can assist you in selecting the type best suited to your particular needs ... recommend designs that will insure maximum service life.

To put such knowledge to work for you, just phone your nearest Electro-Alloys office, or write Electro-Alloys Division, 2099 Taylor Street, Elyria, Ohio.

*Reg. U. S. Pat. Off.



ELECTRO-ALLOYS DIVISION



The world is at your doorstep

When you see the Vancoram trademark you can be assured of the highest quality products it is possible to produce.

The world is truly at your doorstep, for the finest raw materials from the world over contribute to the uniformity, superior quality and

maximum efficiency of VANCORAM products.

To make it easier for you to identify these fine products, shipping drums are now painted a distinctive green with the Vancoram trademark superimposed in white—your assurance of topnotch quality.



VANADIUM CORPORATION OF AMERICA

420 LEXINGTON AVENUE, NEW YORK 17, N. Y. . DETROIT . CHICAGO . CLEVELAND . PITTSBURGH

METAL PROGRESS: PAGE 2

nothing else can do what Microcarb does!

Microcarb is a control system for the carburizing process. It continuously measures something that nobody has ever measured before—the active carbon in a production furnace's atmosphere while the furnace is at work in the heat-treat department. And it automatically, continuously controls the surface carbon content of the steel on the basis of this measurement.

Microcarb is many things to many men, especially in defense work.

To top management, Microcarb means both higher product quality and lower unit cost! Also, it means that still another manufacturing operation comes under automatic control.

To production executives, Microcarb means closer following of manufacturing schedules, because carburizing speed and results are more predictable. More predictable, that is, even than with our own pre-Microcarb processing installations. And Microcarb helps heat-treaters apply their skill—helps them earn incentive pay.

To metallurgists, Microcarb means simply better carburizing. Perhaps you saw a recent magazine advertisement headed "Thank You, Leeds & Northrup!" in which Indiana Gear Works credits Microcarb as a "big help to the gear industry" and says

"now, for the first time, we are able to control case carbon content on carburized parts"

"... we can produce carburized surfaces with absolute uniform control and obtain absolute maximum hardness and maximum ductility"

"no more retained austenite on wearing surfaces of high nickel steels"

"... no more carbide networks in the hypereutectoid zone"

Such results trace back to the fact that with Microcarb the carbon you "set" is the carbon you get. Just as you set a temperature controller at 1700 F, if that is the carburizing temperature you want, so you set the Microcarb Controller at 90 if you want to carburize to ninety carbon. By making the proper setting, you can either protect the surface or add

carbon. Instead of controlling the amount of carbon material supplied to the process, you actually control the amount that does the work. Can you imagine controlling the temperature of a furnace by just measuring the amount of fuel it gets, without a pyrometer to tell the temperature directly? Well, that's the kind of carbon control you have always had—until Microcarb. Microcarb measures and controls carbon directly, just as a pyrometer measures and controls temperature directly.

The "reason why" for Microcarb is its carbon-detecting element. This instrument, called a Carbohm, is an engineering rarity—a truly new device for sensing a change in its surroundings. Basically, it's a wire, made of an alloy which will either absorb carbon from the furnace atmosphere, or lose it to the atmosphere, until it and the atmosphere are in equilibrium, carbon-wise. With every change in the wire's carbon content, there's a change in its electrical resistance. This resistance is measured and translated into carbon percentage by the Microcarb recorder and controller.

Only Homocarb Furnace equipments of our new Series H can be used with Microcarb Control, because engineering to meet the needs of atmosphere regulation is a necessity. Specific features are a soundly designed electric furnace with solid-bottom retort, improved fan housing and work support, and aerodynamically designed discharge jets; and Micromax temperature control of the duration-adjusting type specially designed for this service.

Let us send you further facts about this new Microcarb development. Ask our nearest office, or 4927 Stenton Ave., Phila. 44, Pa., for Catalog T-623.



TD4-623(3)

SEPTEMBER 1951: PAGE 3

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Out of this unique "forging laboratory" have come many significant advancements ... the high speed forging press ... modern horizontal Forging Machine ... blank-preforming Reduceroll ... Semi-Hot Rivet Header ... Boltmaker ... roll-over transfer Cold Nut Former ... Automatic Precision Nut Tapper ... Nail-Maker ... Cold Headers for bearing rollers and balls, for tubular and solid rivets, and thousands of other parts ...



In addition, we've been continually developing new forging applications and methods right along . . . establishing basic principles of die design as influenced by metal flow, both hot and cold . . . upsetting . . . deep piercing . . . extrusion . . .

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Hartford Detroit Chicago

METAL PROGRESS; PAGE 4

ORDERS Greetings NOX-RUST CHEMICAL CORPORATION RUST PREVENTIVE DIVISION 2429 SOUTH HALSTED STREET, CHICAGO 8, ILLINOIS BALTIMORE - PHILADELPHIA - DETROIT - SAN FRANCISCO

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Just call NOX-RUST. Chances are an existing product can fill the bill for you. Or, NOX-RUST can build a product around your problem, as they already have done for many major corporations. For complete information, call or write NOX-RUST today.



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Here's a NEW way to package ports and machines without oil or greese coatings. NOX-RUST's new Yapor-Wrapper delivers year pack "foctory fresh"—sparkling clean—ready for immediate assembly or use. Send for the "MOW" beak

that shows case histories of how others have eliminated steshing and de-greating problems with Vapor-Wrapper. It's yours FREE . . . from NOX-RUST—Headquarters for all flust Proventive Products.

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processed to assure highest purity and uniformity

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only PARKER offers you Our Experience In solving problems in cold drawing and cold extrusion

Use of Bonderite to improve difficult drawing began 10 years ago, established a new and accepted technique. In laboratories and mills Parker research and field engineers worked with manufacturers to perfect this method. Parker's affiliate in Germany, beader in development of the technique in Europe, has constantly added its knowledge and experience.

Every year, and every installation, has contributed to Parker knowledge and practical experience—and recognition as authorities in this field of metal treatment.

90% of all cold drawn seamless steel tubing is treated with Bonderite as an aid in drawing.

*Metallgesellshaft, Frankfurt

Advantages of Bonderite in cold drawing and cold extrusion are many and worthwhile: Faster drawing; heavier reductions; longer tool life; reduced metal-to-metal contact; reduced galling and welding because Bonderite acts as an anti-flux; less scrap; fewer rejects, and greater over-all operating economy.

Do you have cold drawing or cold extrusion prob-

Do you have cold drawing or cold extrusion problems? Take advantage of the 10 years' knowledge and successful heavy-production experience of the leader in the field! Write or phone Parker today!

COMPLETE DRAWING SERVICE—Parker has everything you need—cleaners, rinses, Bonderite, and lubricants—all of them keyed to superior cold forming. Plus expert engineering guidance. Write for full information.

Bonderite, Parco, Parco Lubrite-Reg. U.S. Pat. Off.

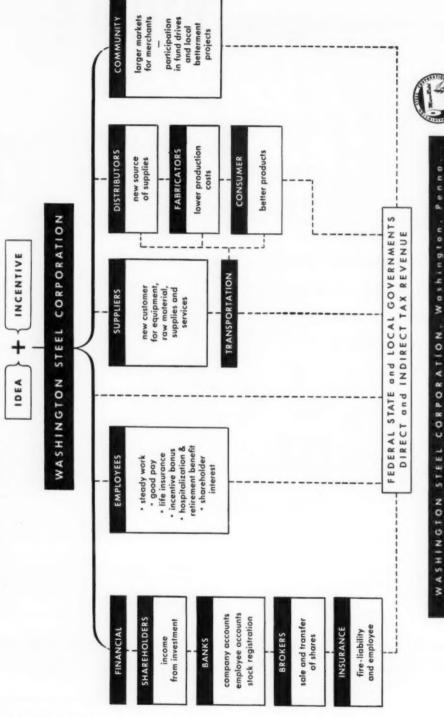
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manufacturers of MesoRold stainless steel sheets and strip

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Ajax Submerged Electrode Furnaces", equipped with refractory pols, reduce maintenance costs to the vanishing point because pot and electrode life is measured in years.

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HEATING FOR FORGING

1.5" become work beauti

DESCALING

CARBURIZING

Monte you turbine buckers
Stelleless circums engine parts

CTRIC

SEPTEMBER 1951; PAGE 9

for DC Heliwelding



AIRCO THOR-TUNG **ELECTRODES**

Here's a tungsten electrode that's especially designed for all positions on straight polarity, DC Heliwelding on stainless steel, copper, mild steel and aluminum, using Heliwelding, Airco's inert gas arc welding process. Made with thoriated tungsten, long-noted for its excellent electron emission characteristics, Airco Thor-Tung offers these advantages -

IT DOESN'T MELT . . .

Airco Thor-Tung does not "ball up" at the end of the electrode nor does it sputter off into the puddle when subjected to high arc welding temperatures - because of its cool operating characteristics, longer life is obtained from each electrode.

NO CONTAMINATION . . .

Airco Thor-Tung permits the operator to "touchstart" directly on the work without contaminating the work or the electrode. Uncontaminated electrodes increase production and result in better welds.

EXCELLENT ARC STABILITY . . .

One of the keys to consistent weld quality and ease of operation is good arc stability. With Airco Thor-Tung, the arc is very stable and does not wander or climb up the electrode even at low currents. Touch starting is made easy even with currents as low as 15 Amperes. The better stability of these electrodes enables a given size to be used over a wider range of currents.

ECONOMICAL . . .

Thor-Tung's permanency, ease of operation and stability make it the most economical electrode for straight polarity, DC Heliwelding.

For full information about Airco Thor-Tung, write your nearby Airco office today.



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MADE OF CONTINUOUS CAST BRONZE!

An aircraft engine manufacturer states that the first 30,000 bushings made

of Asarco Continuous Cast Bronze (75% Cu, 5% Sn, 20% Pb) were tested with black light. There were NO REJECTS! Inspection by this means was discontinued as no longer necessary.

Asarco Continuous Cast rods, tubes and shapes offer production

Asarco Continuous Cast rods, tubes and shapes offer production economies which are unique. Porosity is virtually non-existent. No sand, dirt or other foreign matter is used in the casting process, so that there are no inclusions to harm tools. Cutting speeds can be high, too. All stock for machining is held to close tolerances and is Medart straightened. Tube concentricities are within 1.5% of wall thickness. Continuous Cast Bronzes are ideal for use on automatic screw machines.

You can get Continuous Cast Bronzes made to order in a wide variety of alloys... in standard lengths of 12'... lengths 5' to 12' on request... lengths 12' to 20' on special arrangement.

216 sizes of the standard Asarcon 773 bronze (SAE 660) are stocked in 105" lengths for convenience at warehouses in principal cities across the country. Distributors will cut the warehouse stock long or short to suit your specific requirements.

> Send for a free catalog on Asarco Continuous Cast Bronzes. It contains physical properties, photomicrographs, table of stock shapes and sizes, weights and other valuable information.



POROSITY VIRTUALLY ELIMINATED WITH CONTINUOUS CAST BRONZES

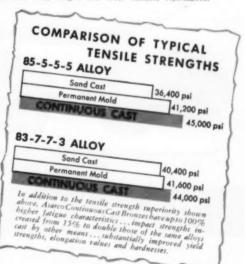
Note in these photomicrographs the superior dispersion of constituents in the continuous cast alloy . . . also its outstanding freedom from metal faults.



West Coast Sales Agent: KINGWELL BROS. LTD., 444 Natoma Street, San Francisco, Calif.

American Smelting and Refining Company
OFFICES: Porth Amboy Plant, Barber, New Jorsey

Whiting, Indiana





The original PSC carburizing box, now the most widely used in industry.



Perforated basket, illustrating the strength and light weight of PSC units.



An example of the many special-purpose boxes we design and fabricate.



Retort and ring for gas carburizing furnace; all light gauge welded alloy.

for these Carburizing Carriers

PSC issues no claims for super service...

but a Good, Time-Proven

Guarantee of Satisfaction

For years we have been guaranteeing PSC of carburizing containers. It is our feeling portained that this gives more assurance than would claims based on cases where pSC equipment gave remarkably long service. Too many variables are inserviced. We believe what is most volved. We believe what is most important to the purchaser of important to the purchaser of is the breadth and is the breadth and

of the maker's know-how. So may we point out that PSC was a pioneer, and is now the largest manufacturer of carburizing containers. PSC welded alloy heat-treating units are furnished in any size, design or metal specification: annealing and carburizing to boxes, fixtures, retorts, covers, etc. Send blue prints or write as to your the needs.



A "PSC" designed-forthe-job fixture; this one eliminated three handlings.



Chimney type boxes for carburizing ring gears, furnished in any size.



Light-weight boxes for easy handling, yet will not warp. In any size.



Stack type baskets for small lots of different parts in gas furnaces.

THE PRESSED STEEL COMPANY

Industrial Equipment of Heat and Corrosion Resistant WEIGHT-SAVING Sheet Alloys

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"So satisfactory we've ordered another"

"Our Westinghouse Furnace has proved so satisfactory that we've ordered another one", says Marlin-Rockwell Corporation, Plainville, Connecticut—manufacturer of ball bearings.

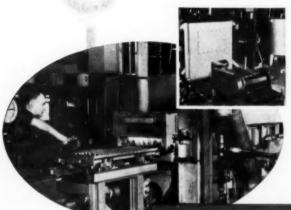
"The furnace has resulted in at least 50% improvement in the production-perman-hour ratio over the system we previously used. Controlled feeding of small bearing rings and retainers permits gradual heating. This, along with controlled temperature of the quenching bath, practically eliminates distortion.

"Proper atmospheric control provides the right bright-hardening, entirely eliminating sandblasting. Our bearings have a better finish, and are a better product."

Gas-fired or electric, there's a Westinghouse Furnace to meet every heattreating need. Westinghouse Electric Corporation, Industrial Heating Works, Meadville, Pennsylvania.

J-10368





IF YOUR PRODUCT CALLS FOR
HEAT-TREATING...IT CALLS
FOR A WESTINGHOUSE FURNACE...
GAS OR ELECTRIC

Westinghouse

HEAT-TREATING FURNACES





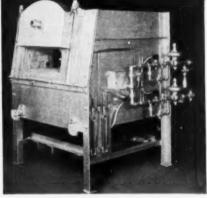
SUNBEAM STEWART Industrial Furnace Division of Sunbeam Corporation builds this gas-fired oven furnace for tool rooms and shops. It operates over a 300-2400° F range, and employs an unusual semi-muffle which can be converted to a full muffle for atmospheric hardening. CARBOFRAX shapes are used for this muffle to secure faster, more uniform heating and to resist abrasion and heat shock.



Most builders of heat-treating furnaces agree that somewhere in almost every furnace Super Refractories can be used to advantage.

CARBOFRAX silicon carbide material, for example, is an excellent conductor of heat. Used for muffles or hearths, it means faster heat flow, more uniform heating—with an improvement in quality of treatment and usually with a saving in fuel. It is also outstanding in resistance to abrasion and heat shock.

There are other Super Refractories by CARBORUNDUM, each with distinctive properties. All are covered in a 40-page booklet, "Super Refractories for Heat Treatment Furnaces." May we send you a copy?



DEMPSEY INDUSTRIAL FURNACE CORP. builds this gas-fired atmospheric-type furnace which operates at temperatures as high as 2400°F. In this furnace the muffle is of CARBOFRAX material to improve the niformity of treatment, secure maximum production and to minimize maintenance and replacement expense.



JOHNSON GAS APPLIANCE CO.

manufactures this gas-fired furnace which is especially designed for heat-treating small tools, dies and other small parts. It is used for temperatures up to 2400°F. In this furnace the hearth is of CARBOFRAX tile which transmits heat rapidly and evenly to the work—and resists the abrasive action of the charge.

THE CARBORUNDUM COMPANY

Dept. C-91, Refractories Div.

Perth Amboy, New Jersey

'Carborundum'' and ''Carbofrax'' are registered trademarks which indicate manufacture by the Carborundum Company

Streamlined SPEED PRESS

The most advanced design in press equipment for speed, convenience, and stanomy in the production of Bakelite and Transparent Molded Specimen Mounts ever presented to the metallurgist.

A revolutionary teature introducand in this new press is preheated.

Premaids. The preheat compartment reduces the curing time of thermosetting molds to one-third of the time usually required. It enables the aperator is produce perfect Bakelite Mounts in 2½ to 3½ minutes. All necessary indicators and controls including pressure gauge, pyrameter, thermostals, timer and pilot lights are provided. No experience is required to produce perfect mounts. Automatic ram retraction saves time and effort.

The hinged press head is made with a semi-automatic lack and a hand wheel screw to close the mold securely. Heating blacks are auranged with a magnetic closure to snugly envelop the mold assembly. The interchange of thermostatically controlled heating units of 600 watt capacity is facilitated by convenient supports. Cooling blacks are lacated in a practical position in front of the press cabinet.

this new speed press is the result of long exacting experiment, with every effort devoted to designing the linest modern specimen press we are able to engineer.

THE BUEHLER LINE OF SPECIMEN PREPARATION EQUIPMENT INCLUDES . . . CUT-OFF MACHINES . . SPECIMEN MOUNT
PRESSES . POWER GRINDERS . DISC GRINDERS . HAND GRINDERS . . BELT SURFACERS . MECHANICAL
AND ELECTRO POLISHERS . POLISHING CLOTHS . POLISHING ABRASIVES.

No. 1330 AB Speed Press, mountings \$420.00

\$440.00

\$460.00

complete for 1" mountings

No. 1330-2 AB Speed Press, complete for 11/4" mountings

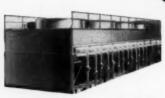
Na. 1330-3 AB Speed Press, complete for 11/2"

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INDUCED DRAFT—High velocity air discharge prevents recirculation in congested areas: allows complete freeze-up protection in cold



FORCED DRAFT-Most accessible installation mechanical parts are placed beneath coils. Economical in first cost and in fan horsepower



SMALL UNITS-A typical installationpower generating plant. Smaller horisontal and vertical portable units are available.



MECHANICAL PARTS-Adjustable fans. fan hubs. Geareducers, driveshafts, couplers are Marley designed exclusively for cooling unit





MARLEY

Makes a World of Difference in **Diesel Operation**

DriCoolers are the air cooled heat exchangers that do a precision job of cooling high temperature jacket water and lube oil. DriCooler ability to pin-point operating temperatures as recommended by engine manufacturers assures maximum fuel economy, smooth operation and long service life.

DriCoolers are produced in such a broad range of models and sizes that they provide efficient cooling for engines from 50 hp. to 5000 hp. They are applicable to any climatic conditions - are now in operation from Alaska to Arabia.

OUTSTANDING DRICOOLER FEATURES * Induced or forced draft designs to fit varying applications * Marley-design headers permit unusual flexibility of coll arrangement * Extra strong truss construction—either all steel or asbestor-board covered redwood frame * All mechanical equipment is designed, manufactured and guaranteed by Marley-proved by years of service in thousands of installations.

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Mariey Company, Inc.

Kansas City 15, Kansas

ALSO PRODUCERS OF WORLD'S MOST COMPLETE LINE OF WATER COOLING TOWERS

METAL PROGRESS; PAGE 16



"Forgings by Finkl"...a byword in the industry...the best obtainable. "Forgings by Finkl" means that skilled craftsmen, employing modern methods and machinery, have selected the best steel for the job and created the best job from the steel. And to doubly insure long life and economical performance, each step in the development of the forging is thoroughly checked metallurgically. Nothing is taken for granted.

A medium size forging, illustrated above, is the top head for a 2,000 ton hydraulic press. It is made of C-1045 steel, normalized and drawn in one of Finkl's heat treating shops. Forged from a 59" ingot, the rough machined forging shown weighs 22,800 pounds. Whether carbon or alloy steel, the Finkl organization can easily handle any job from a few pounds up to 50,000 pounds apiece.

Write or phone when you are ready to talk about or plan your forgings. The experience of Finkl Sales Engineers is available to you.



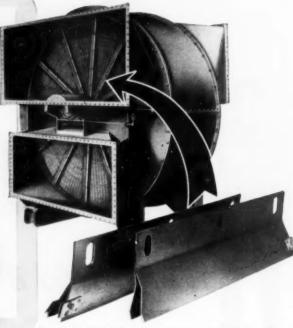
MANUFACTURERS OF THE LARGEST FORGINGS IN THE MIDDLE WEST

A. Finkl & Sons Co.

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DIE BLOCKS & INSERTS . PISTON RODS & RAMS . SOW BLOCKS . CRANKSHAFTS

Eliminates 3 to 6 Costly Shutdowns



In general, corrosion in air preheaters occurs at the seals on the cold end, where corrosive sulphides and chlorides condense from hot flue gases on the cold metal. At this key point, HASTELLOY alloys last 3 to 6 times longer than other metals.

Air Preheater Seals of HASTELLOY Alloy Last 11/2 to 2 Years in Presence of Sulphides, Chlorides, and Metallic Compounds

Use of preheated air has resulted in considerable savings at several refineries where HASTELLOY alloy has helped to eliminate the severe corrosion problem often encountered at the cold end of the preheater units. The radial, circumferential, and post seals ordinarily used in this service leak and overload blower motors after only 3 to 6 months because of the corrosive flue gases, which condense when they strike the cold metal. Before the refineries switched to HASTELLOY alloy, a maintenance and replacement costs frequently canceled out much of the saving in fuel consumption and

other advantages of reclaiming waste heat from most reaction processes.

Seals made from HASTELLOY alloy are not readily attacked by the refinery gases, which usually contain sulphides and chlorides, as well as compounds of vanadium, arsenic, and other metalloids and metals. Equipment can be run continuously for as long as 18 months to 2 years without shutdown for the replacement of seals.

For complete data on Hastelloy alloys, write for the 40-page booklet, "Hastelloy High-Strength, Nickel-Base, Corrosion-Resistant Alloys."

HAYNES alloys

Haynes Stellite Company

A Division of Union Carbide and Carbon Corporation

General Offices and Works, Kokomo, Indiana Sales Offices

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Los Angeles — New York — Son Francisco — Tulsa

"Havnes" and "Hastelloy" are trade-marks of Union Carbide and Carbon Corporation.

METAL PROGRESS: PAGE 18

"EDCO Dowmetal BOTTOM BOARDS

have resulted in tremendous savings for our foundry

... says M. C. Crawford of RILEY STOKER CORPORATION



Christiansen Corporation 1515 North Kilpatrick Ave. Chicago 51, Illinois

May 16, 1951

Attn: Mr. Edw. S. Christiansen, Pres

Gentlemen:

Before the purchase of EDCO Downetal Bottom Boards, we made our care and bottom Boards, we made our care and cost of approach and cost of a cost of approach and cost of a cost of approach and approach approach and approach a

RILEY STOKER CORPORATION

M. C. Crawford Director of Purchases Detroit Plant

Above photo thows molder of filey Staker Carporation placing EDCO Bottom Board on flask preparatory to presing. EDCO DOWMETAL magnesium boards maintain high quality of castings and reduce rejects because the exclusive greaved and vented design permits escape of gasses and insures mold stability.

Progressive foundry operators, like Riley Stoker Corporation, are equipping their foundries with EDCO DOWMETAL Bottom

Made of magnesium, these boards will not warp or break. There are no nails to come out, nothing to break or split—no upkeep! So durable, they can be considered permanent equipment. The many advantages from the use of these boards are effective immediately on the installation. on their installation.

Write us or phone CApitol 7-2060 today for complete price schedule and list of 74 standard sizes available from stock.





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MANUFACTURERS OF CARBON ALLOY AND YOLOY STEELS

The steel industry is using all its resources to produce more steel, but it needs your help and needs it now. Turn in your scrap, through your regular sources, at the earliest possible moment.



Designed for Durability!

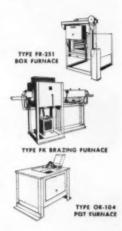
Hoskins Chromel*-equipped Electric Heat Treating Furnaces

Take a good look inside any Hoskins Electric Furnace and you'll quickly understand why they're known for dependability. For beneath their sturdy rugged external construction . . . inside their heavy heat-containing insulation . . . you'll find that every one is equipped with long-lasting heating elements made of CHROMEL resistance alloy.

CHROMEL, you know, is the original nickel-chromium alloy that first made electrical heating practical. It's highly resistant to oxidation . . . possesses close-to-constant "hot" resistance between 700° and 2000° F., delivers full rated power throughout its long and useful life. And, as the most vital part of every Hoskins Furnace, it represents your best assurance of long-life satisfactory service.

So next time you're in the market for good, dependable heat treating equipment . . . equipment designed for durability, efficient low-cost operation, and the production of uniformly high quality work . . . you'll do well to get the facts on the Hoskins line of CHROMEL-equipped Electric Furnaces.

Our Catalog 59-R contains complete information . . . want a copy?





NEW YORK • CLEVELAND • CHICAGO
West Coast Representatives in Seattle, San Francisce, Los Angeles
In Canada: Walker Metal Products, 1td., Walkerville, Ontario

*the orner to kel-chromium resistance alloy that first made electrical heating practical

How can I keep furnace fuel costs down?

Back up with SIL-O-CEL Insulating Brick!



3 economical answers to high-temperature insulation problems

NATURE HERSELF has produced one of the most effective high-temperature insulating materials ever discovered-diatomaceous silica, from which Sil-O-Cel® Insulating Brick are made.

These insulating brick are used for back-up insulation behind fire brick or insulating fire brick linings in boilers, stills, stacks, heat-treating furnaces, kilns, lehrs, flues, retorts, and other types of high-temperature equipment.

Sil-O-Cel Insulating Brick have excellent insulating qualities combined with high load-bearing characteristics and light weight.

Made in all standard shapes of the 21/2 in. and 3 in. series, Sil-O-Cel Insulating Brick are produced in three basic types:

SIL-O-CEL NATURAL INSULATING BRICK for temperatures to 1600F

Quarried directly from one of the world's purest deposits of diatomaceous silica, these insulating brick have a conductivity of only 0.79 Btu in./sq ft/F/hr at 1000F mean temperature, with heat flow perpendicular to brick strata. Yet their density is only 30 lb/cu ft. Cold crushing strength, 400 psi.

SIL-O-CEL C-22 INSULATING BRICK for temperatures to 2000F

Ideal where high load-bearing properties are needed, this type of Sil-O-Cel is calcined, and has a cold crushing strength of 700 psi. Conductivity is 1.88 Btu in./sq ft/F/hr at 1000F mean temperature. Density, 38 lb/cu ft.

SIL-O-CEL SUPER INSULATING BRICK for temperatures to 2500F

A calcined insulating brick for unusually high temperatures. In many cases, it is also possible to save on construction costs by reducing the thickness of fire brick or insulating fire brick when backed with Sil-O-Cel Super Insulating Brick. Conductivity is 1.95 Btu in./sq ft/F/hr at 1000F mean temperature. Density, 40 lb./cu. ft. Cold crushing strength, 300 psi.

For further information, write to Johns-Manville, Box 290, New York, N. Y. In Canada, write 199 Bay St., Toronto 1, Ont.





Johns-Manville Livet in



INSULATIONS

SHOP LABOR SHOP TIME GRINDING COSTS

GROUND and POLISHED

STRESSPROOF PROVIDES

4 UN 1 BAR

1. Eliminates Heat Treating

Its in-the-bar strength, as received, is twice as great as ordinary coldfinished steel shafting.

2. Eliminates Case Hardening

Its resistance to wear, as machined, is sufficient to replace many heat-treated or carburized steels.

3. Minimizes Warpage

Because it is stress-relieved, this superior bar assures the user a minimum of distortion.

4. Speeds Up Machining

Has in-the-bar machinability fully 50% better than heat-treated alloys of the same hardness.

Many companies are realizing important savings by using Ground and Polished STRESSPROOF bars instead of grinding the steel in their own shop. For this superior steel provides precision tolerances at a reasonable cost, without tying up valuable labor and machinery.

This all-purpose bar stock is ground to close tolerance and highly polished at the LaSalle plant on batteries of modern machines—at lower cost than you can grind it yourself. Furthermore, because this versatile steel is stress-relieved, it requires no straightening after keyscating, journaling, threading, or other machining operations. And its four qualities in-the-bar eliminate many other costly operations.

Almost all of today's Ground and Polished STRESSPROOF production is going into defense jobs. However, from time to time, some sizes of sample bars may be available for testing purposes.

La Salle STEEL CO.

1424 150th Street, Hammond, Indiana





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INTERNATIONAL HARVESTER

make better equipment

IH can now forecast ... with high accuracy ... the behavior of metals used in building equipment for long and satisfactory service.

Here is how IH research men go about it.

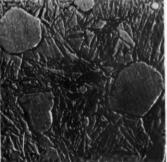
With the RCA Electron Microscope, they observe the minute particles in the metals. They study the effect of carbide particle size on metal properties, make quantitative volume studies of different phases, analyze the structural changes accompanying the tempering of martensite-and uncover new important and essential facts that help solve many manufacturing problems in the laboratories and factories!

Consider the possibilities of this powerful instrument in your own research and production operations. You can obtain sharp images at direct magnification from 500 to 23,000 diameters, with photographic enlargements up to 100,000 diameters. You can resolve detail from 20 to 50 times finer than the best light microscope. You can bring every level of the specimen into sharp focus-regardless of the magnifying power you choose. You can also employ this versatile instrument for electron diffraction studies.

For complete data, write Dept. 72 U. RCA Engineering Products, Camden, N. J.



IH researcher observing a sample of steel in the RCA Electron Microscope. This instrument aids him in measuring carbide particle size and distribution-to predict the performance

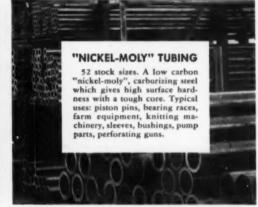


2.2% carbon, 12% chromium tool steel-magnified 7000 x by the RCA Flectron Microscope. The approximately round islands are carbides; the irregular islands are austenite: the somewhat rough surface comprises martensite. The specimen was mechanically polished and etched with 4% picral. A replica was made of Formvar, then shadowed with chromium.

Tight steel supply got you in a pinch?



52100 TUBING 101 stock sizes. A high carbon chrome, direct quenching steel which gives through hardness in moderate sections. Typical uses: aircraft parts, slitter knives, bearing races, pump parts and plungers, collets, bushings, spindles, grinding machines, precision instruments.



These two TIMKEN® steels will do 90% of your hollow parts jobs

and are available now in warehouse lots!

If rush jobs find you short of steel tubing, get in touch with the Timken Company. The two Timken steels described above—52100 tubing and "Nickel-moly" tubing—will do 9 out of 10 of your hollow parts jobs. And we guarantee shipment of warehouse lots within 24 hours after receipt of order.

We maintain a mill stock of 101 sizes of 52100 tubing —from 1" to 10½" O.D. This analysis is through-hardening in moderate sections. It can be heat treated to file hardness and tempered back to any point you want. There

are 52 stock sizes of "Nickel-moly" tubing—from 1 1/4" to 10 1/4" O.D. With heat treatment, it develops exceptional shock absorbing qualities.

Uniformity in every shipment is assured by the Timken Company's complete, rigid quality control from melting through final inspection. For the current mill stock list, write on your company letterhead to The Timken Roller Bearing Company, Steel and Tube Division, Canton 6, Ohio. Cable address: "TIMROSCO".

TEARS AHEAD-THROUGH EXPERIENCE AND RESEARCH

STEELS

STEELS

And Seemlow Trabes

Specialists in allow steel-including hot rolled and cold finished allow steel bars-a complete range of stainless, graphitic and standard tool analyses-and allow and stainless seamless steel tubing



Photo courtesy of Walla Walla College, Walla Walla, Washington

another OLSEN SUPER "L" training tomorrow's engineers

Put an Oisen in your plant and gain all of the advantages of low-cost testing with high accuracy.



Engineering schools and colleges as well as industries all over the country are enthusiastic about the Olsen Super "L" with Selec Trange indicating system which reduces accurate testing to its utter simplicity—a 50 to 1 ratio of testing ranges—change from one range to another during test—automatic lighting of range in use; 3 ranges on one 28" dial.

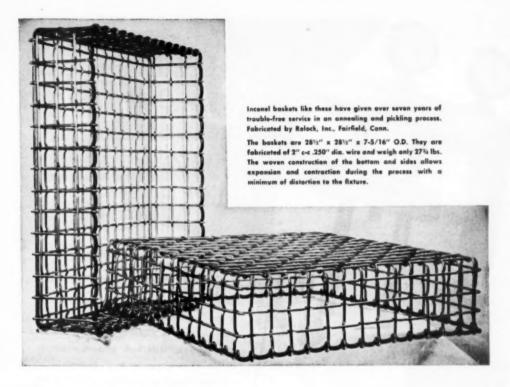
The 60,000# machine shown has 14 inch span between screws; it is also available with 30 inch span.

The Olsen Super "L" is the best buy in universal testing machines available today. It is low in cost, ruggedly constructed with traditional Olsen workmanship, and meets ASTM, governmental and service specifications. WRITE TODAY FOR BULLETIN 40.

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Testing & Balancing Machines

TINIUS OLSEN
TESTING MACHINE CO.
2030 Easton Rd. Willow Grove. Pa.



7 years service in an annealing furnace...and still on the job!

These conveyor baskets for annealing and pickling brass shell cases have to be rugged.

Here's what they have to stand up against.

First they must carry 200 to 300 pounds of brass shell cases through an annealing furnace with temperatures up to 1100° F. for as long as $2\frac{1}{2}$ hours. Then they are spray-quenched with water. Then they are put into a pickling solution of from 10 to 15% sulfuric acid at temperatures of 140° to 130° F.

A material, to give day-after-day service under conditions like these, must have unusual qualities.

And Rolock, Inc., metal fabricators, knew that material—Inconel®!

The baskets were designed and fabricated over seven

years ago. They have been in almost daily use ever since — yet they have not suffered any significant attack by corrosion.

That's because Inconel is highly resistant to destructive oxidation, corrosion, heat-cracking, and embrittlement, even at temperatures as high as 2000°F.

Like Rolock, leading fabricators throughout the country have made Inconel the standard metal for high-heat applications. But right now, Inconel is hard to get because so much is being diverted to defense. Your own fabricator will be able to tell you about present availabilities.



THE INTERNATIONAL NICKEL COMPANY, INC.
67 Wall Street, New York 5, N. Y.

INCONEL . . . for long life at high temperatures



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Phree calibrated test blocks, flat and 'V' anvil, convex anvil, diamond and indentors. Weight only 6 lbs., 7 ex.

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- . COMPRESSION TESTING MACHINES
- . IMPACT TESTERS
- . TORSION TESTERS
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"ONE TEST IS WORTH A THOUSAND EXPERT OPINIONS"

Engineering Digest

OF NEW PRODUCTS

SPOT WELDING AND SOLDERING MACHINE: A new welding and soldering machine by Joyal Products is of particular interest to the manufacturer of small products. It solders or welds in less than a second. It spot welds steel parts up to 32 in., and will solder brass up to 1/4 in. thick, as well as sterling silver and other precious metals. An automatic cutoff timer regulates soldering time. Heat control with eleven adjustments determines correct heat for the job. When dials are set, uniform soldering time, heat, and holding pressure on the electrodes are maintained, regardless of how long the foot switch is held down

For further information circle No. 268 on literature request card on p. 32B

HIGH-VACUUM PUMP: A new microvac pump has been put on the market by the F. J. Stokes Machine Co. It has a capacity of 500 cu.ft. per min, and is suitable for any type of vacuum processing work. A watercooled unit which operates at 390 rpm. with a top-mounted 25-hp. motor, it weighs 2400 lb. and is 76 in. high. It operates at a high volumetric efficiency because there is a complete discharge of air at each stroke, with no chance for re-expansion. With only four moving parts and low relative surface motion of piston to housing, minimum wear and low upkeep can be expected.

For further information circle No. 269 on literature request card on p. 32B

LABORATORY APPARATUS: RCA announces a low-cost unit to speed preparation of shadow-cast specimens for the electron microscope. The apparatus permits laboratory personnel to deposit a thin coating of tungsten, molybdenum or other suitable material by evaporation on as many as six glass microscope slides at one loading in the all-metal vacuum chamber. The unit consists of a small steel vacuum chamber which is evacuated at high speed by an oil diffusion pump, backed by a mechanical fore pump. The entire unit, with the exception of the fore pump, is contained in a steel cabinet 14 by 14 by 10 in. and weighs only 40 lb. The power requirement is 700 watts at 105-125 volts, 60 cycles. For further information circle No. 270 on literature request card on p. 32B SOLVENT CLEANER AND ADDITIVE: The Magnus Chemical Co. has announced that Magnusol, an emulsifiable solvent cleaner, can also be used as an additive to forming, cutting and stamping oils to act as insurance that the existing cleaning method will continue to do the job expected of it, regardless of any changes made in the formula of the lubricating compounds. For further information circle No. 271 on literature request card on p. 32B

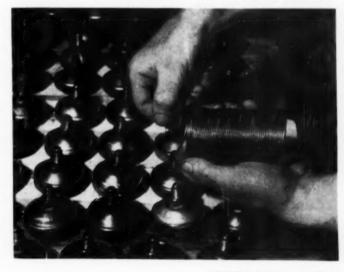
SHEET METAL TESTER: J. Arthur Deakin & Son are introducing G. H. Alexander's tester for making the Erichsen test for workability and fracture of sheet metal. It will handle material up to & in. thick. In testing, readings accurate to 0.0004 in. are obtainable. Test pleces 3½ in. square and strips up to 2½ in. wide can be tested with standard tools. Additional interchangeable tools can be supplied for checking narrow strips.

For further information circle No. 272 on literature request card on p. 32B

VERNIER POWER FEED: The DoAll Co. announces an improvement of power feed control on their hydraulically operated band tooled machine which will give the operator more sensitive control of the hydraulic table when sawing thick steel sections or when line grinding or diamond-sawing hardened alloys. The table in-feed knob has an added vernier control at the side which enables the operator to start a cut with a low feed rate.

For further information circle No. 273 on literature request card on p. 32B

FLAT WIRE PREFORMS: Flat wire "No-Tangle" notched-coil stressrelieved silver brazing and soldering rings for faster, more economical and improved brazing of armed forces projectiles and other ordnance equipment and supplies are now available from the Lucas-Milhaupt Engineering Co. These flat wire preforms were especially designed for applications requiring larger volume of silver alloy for added strength in critical joints and where the depth and shape of the groove prohibited use of round wire rings. Flat wire rings can be made in unlimited, job-determined diameters and wire thicknesses in butt, lap and gap form. Because they are flattened to individual job specifications, new rings provide a more complete fill and a stronger, leak-proof bond. Stressrelieved rings retain a plus and minus 0.001-in. tolerance under all conditions and do not distort or fall away from the workpiece when heat is applied. Stress relieving permits gap rings to be compressed easily into grooves in inner diameter applications. Released, they expand automatically to specified diameter. Lap and butt rings are designed for close tolerance applications on keyed and nonkeyed outer surfaces. For further information circle No. 274 on literature request card on p. 32B



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(t's this simple: Select the Tempilstik® for the working temperature you want. Mark your workpiece with it. When the Tempilstik® mark melts, the specified temperature has been reached.



| Availab | le in t | hese te | mperatu | res (°F |
|---------|---------|---------|---------|---------|
| 113     | 243     | 400     | 950     | 1500    |
| 125     | 275     | 450     | 1000    | 1550    |
| 138     | 288     | 500     | 1050    | 1600    |
| 150     | 300     | 550     | 1100    | 1850    |
| 163     | 313     | 400     | 1150    | 1700    |
| 175     | 325     | 450     | 1200    | 1750    |
| 188     | 338     | 700     | 1250    | 1800    |
| 200     | 350     | 750     | 1300    | 1850    |
| 225     | 343     | 800     | 1350    | 1900    |
| 238     | 375     | 850     | 1400    | 1950    |
| 250     | 388     | 900     | 1450    | 2000    |

FREE -Tempil' "Basic Guide - 16½" by 21" plastic-laminated wall chart in color. Send for sample pellets, stating temperature of interest to you.



AUD S. GORDON CO

Manufacturers & Distributors couple Supplies - Industrial Furnaces & Ovens ters & Controls - Metallurgical Testing Machines pt. 15 - 3000 South Wallace St., Chicago 16, III. pt. 15 - 2035 Hamilton Ave., Cleveland 14, Ohio

### Tempilstiks Engineering Digest

NEW PRODUCTS

ISOMA HARDNESS TESTER: The Cosa Corp. is introducing in the United States the Isoma tester for measuring Vickers hardness on small round and flat metal parts, foil, tinplate and other materials. This tester



has an automatic weight selecting device for applying dead weight loads from 50 to 1000 g. The minimum thickness of flat pieces to be tested is 0.0005 in. Minimum diameter for rounds is from 0.003 to 0.005 in. Standard equipment includes optical measuring system, transformer for 110 or 220 volts, base plate, test block, spare bulbs and table of equivalent values. Special supports and clamps are available for holding thin material and extremely small parts.

For further information circle No. 275 on literature request card on p. 32B

ARC DRIVE CONTROL: Westinghouse Electric Corp. now has available an arc drive control to produce electrical transient characteristics desirable for certain welding operations. The device operates automatically and instantaneously to provide an extra surge of welding current at the moment the arc becomes shorted. The extra surge of current helps clear the arc path and prevents arc outage or sticking of the electrode. The amount of arc drive desired can be set by the operator and a self-heating thermostat in the arc drive circuit protects it from overheating.

For further information circle No. 276 on literature request card on p. 32B

SOLVENT CLEANER: Du-Lite Chemical Corp. announces the development of a new soak solvent. Designed specifically for a quick removal of buffing and drawing compounds from knurled or fluted surfaces of all metals, it will also remove greases and oils in less than a minute and also can be used for preparing metal surfaces prior to plating, painting, parkerizing, bonderizing and galvanizing. For further information circle No. 277 on literature request card on p. 32B

ELECTRONIC MICROMETER: Rapid and accurate measurements to a tolerance of 0,00002 in, are claimed for the Carson-Dice electronic micrometer manufactured by the J. W. Dice Co. An electronic circuit used in conjunction with an extremely accurate micrometer head permits "pressureless" measurement and eliminates "feel" as a source of error. The electronic circuit is sufficiently sensitive to give positive on-and-off indications with only five millionths of an inch displacement at the contact. The mi-



crometer can be used for rapid measurement of machined parts, ball bearings, small assemblies and depths of counterbore. It can also be used to measure deflections in diaphragms, bimetal elements, springs, bellows and similar applications.

For further information circle No. 278 on literature request card on p. 32B

TEMPERATURE CONTROL: The Model V-1C Water, Vapor and Dust-Tight Temperature Control is announced by the Burling Instrument Co. Interchangeable with other instrument heads, it can be supplied for any temperature from minus 200 to 1400° F. with standard tubes and up to 1800° F. with special tubes. It can be supplied with either microswitches or manual reset switches.

For further information circle No. 279 on literature request card on p. 32B

ELECTRO-MECHANICAL MEAS-URE: W. C. Dillon & Co. announces an improved system for measuring tension, weight or tractive loads remotely. It is electro-mechanical in



design and is now equipped with oversize selsyn motors for added torque and increased dependability. Either one or two repeater stations may be used with each transmitter dynamometer as desired. Distance between each repeater can be varied. It has twelve different capacities from 0 – 500 lb. up to 0 – 50,000 lb.

For further information circle No. 280 on literature request card on p. 32B

THICKNESS TESTER: The Audigage, a portable, self-contained thickness tester, is announced by Branson Instruments, Inc. It can be used to measure steel thickness over a range of & to 12 in., from one side only. It does this by determining the frequency of vibration in the thickness direction. This property is essentially independent of the other dimensions of the material. Designed for one-man operation, the instrument has a conversion scale concentric with the frequency scale and enables the operator to read thickness directly in terms of frequency.

For further information circle No. 281 on literature request card on p. 32B

NEW CONTROL: A new instrument, combining the advantages of pneumatic control and having a calibrated chart 120 ft. long and 11 in. wide, has been developed by the Brown Instruments Div. The new instrument is an electronic potentiometer that has a 10% proportional band, a 150% proportional band and manual reset, or

a 150% proportional band and auto-

For further information circle No. 282 on literature request card on p. 32B

HEATER: The Brown Fintube Co.'s Type 102 Direct Fired Heater consists of a stainless steel outer shell with expansion section and an Inconel center tube with integrally welded extended surface nickel fins. Designed for high fuel and thermal efficiency, the equipment will heat air, special atmospheres, gases or liquids without contaminating them with the products of combustion. With an accurately controlled temperature range to 1600° F., the heaters use either gas or oil as fuel.

For further information circle No. 283 on literature request card on p. 32B

WELDING RODS: Silicon-free, flux-coated aluminum welding rods for oxy-acetylene and oxy-hydrogen welding have been released by the Eutectic Welding Alloys Corp. Manufactured in ¼ and ¾ in. diameters, the rods can be used in applications where an anodized silicon-bearing welding rod has produced an objectionable dark weld.

For further information circle No. 284 on literature request card on p. 32B

CONTINUOUS SAMPLING MONI-TOR: A new electrical device, perfected by General Electric Co., elimi-

fected by General Electric Co., eliminates the complexity of paper work inherent in the continuous sampling methods of quality control. In opera-



tion, a given number of consecutive acceptable units is established by 100% inspection. This "clearance number" and the percentage number to be used for sampling are determined by the desired average outgoing quality level (AOQL) selected from a set of curves supplied with the equipment. Once the clearance number is reached, the operator begins sampling and continues until an unacceptable unit is found. This defective unit is replaced by a good unit and the 100% inspection is followed for another clearance.

For further information circle No. 285 on literature request card on p. 32B



Write for Bulletin N-1. Eclipse Fuel Engineering Company
727 South Main St. Rockford, Illinois

McKee Eclipse

Representatives in all Principal Cities



### Ultrasonic REFLECTOSCOPE

TEST NEW MATERIAL at the mill to improve quality and customer acceptonce. TEST METALS PRIOR TO PROCES. SING, MACHINING AND FABRICATING to avoid wasted machine time and manhours resulting from faulty materials. QUALITY CONTROL of work in process. MAINTENANCE INSPECTION to detect fatigue fractures. MEASURE PHYSICAL DIMENSIONS. Rely on the ultrasonic Reflectoscope to provide accurate inspection-instantaneously at low cost. Reflectoscopes are available for sale, for rent or lease.

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| IMPROVE QUALITY  | · Therefore |
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| SPERRY           | -           |
| Products, Inc.   |             |
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| TITLE       | -       |             |       |
| COMPANY     |         |             |       |
| CO. ADDRESS |         |             |       |
| CITY        | ZONE    | STATE       |       |

SPERRY ALSO MANUFACTURES COUPLINGS, HYDRAULIC CONTROLS AND OTHER TESTING EQUIPMENT

### What's New

IN MANUFACTURERS' LITERATURE

Alloy Steel

Rooklet on Carilloy steel tells how No. 4150 and others provide toughness, strength and light-veight durability under trying conditions of ervice. U. S. Steel Co.

287. Alloy Steel

Booklet on the selection of the proper alloy steel grades for each manufacturer's needs. Write for "Wheelock Lovejoy Data Book". Wheelock Lovejoy & Co.

288. Alloy Steel

New 16-page, pocket-size booklet entitled "Re-public Alby Steels and How to Get the Most Out of Them" contains seven case histories selected from widely varied fields to demonstrate the versa-tility of alloy steels. Republic Steel Corp.

289. Alloys, Fabricated

Catalog available showing cost-cutting fabri-cated heat treating equipment for higher payloads and better quality. Rolock, Inc.

290. Alloys, Nickel

Hastelloy nickel-base alloys are available for fabricating corrosion-resistant screen, cloth and baskets. Also for metal spraying many types of automatic welding and hardfacing. Booklet. "Hastelloy Nickel-Base Alloys", gives full details. Haynes Stellite Co.

291. Aluminum

Copy of "Alcoa Aluminum Impact Extrusions" will be sent on request, giving (ull information on impact extrusion process and service. Shows whole range of shapes for engineering. Aluminum Co. of America.

292. Aluminum Forgings

To help you in designing for aluminum forgings, a new book is offered, covering relation of forging design to die sinking and relation of forging design to the manufacturing process. Also a section on metallurgy gives all commercial alloy compositions, physical properties and tolerances. Aluminum Co. of America.

293. Aluminum Welding

New control system that extends electrode life for spot welding aluminum, fully described in "Technical Advisor No. 15". Reynolds Metals Co.

294. Arc Welding

Heliwelding, Airco's inert, gas-shielded arc-welding process for all-position welding of alumi-num magnesium, stainless steel, brass and copper-is fully described in ADC-709 Catalog 9. Av. Reduction Sales Co.

295. Belts, Metal

Bulletin 47P illustrates and describes complete line of wire belts for industry. Askworth Brothers, Inc.

296. Brass and Bronze

8-page illustrated booklet on control methods as applied to brass and brass rod, forgings, die castings and welding. Titan Metal Mfg. Co.

297. Brinell

Bench model Brinell hardness tester (Model J) illustrated and described in bulletin. Steel City sting Machines, Inc.

298. Camera, High Speed

"Magnifying Time", a new folder describ-high-speed camera capable of 1000 to 3000 r tures per second. Particularly adaptable for el-inspection in machine tool operations and also measuring flow of liquids as in chemical mix-coolant flow, etc. Eastman Kodak Co.

299. Carbon Control

Catalog T-623 describes the Microcarb control system that continuously measures the active carbon in the furnace atmosphere during heat treatment. Leeds & Northrup Co.

300. Castings

Bulletin FC-350 outlines the many advantages of improved Fabrite corrosion-resistant castings. Ohio Sieel Foundry Co.

301. Cleaning and Buffing

Bulletin 44 contains an interesting discussion of arrel deburring, as well as methods of removing any kinds of burrs from sawing, drilling, milling and stamping operations. Magnus Chemical Co.

302. Cleaning Brushes

New booklet shows 12 actual case histories of how they provide thorough cleaning of welds, stainless sheet, hot cast iron, automotive parts, brass fixtures, and others. Pittsburgh Plate Glass Co., Brash Div.

303. Coatings, Metal

Explanations of high-vacuum evaporation of metals and other solids set forth in detail in new 12-page booklet. "Vaporized Metal Coatings by High Vacuum". Distillation Products, Inc.

304. Coatings, Zinc

to-page illustrated booklet discusses the origin of galvanizing, the various zinc coating methods employed today and the advantages of zinc as a protective coating for iron and steel products. St. Joseph Laud Co.

305. Cold Drawing

Full information available on complete drawing service — cleaners, rinses, Bonderite, and lubri-cants to solve all cold drawing and cold extrusion problems. Parker Russ Proof Co.

306. Combustion Control

32-page catalog 9001 provides a complete manual a flame failure protection for industrial applications. Includes information on new "flame-rectication principle" with installation drawings and unprehensive data on 24 different saleguard hensive data on 24 different sales by Minneapolis-Honeywell Regulator Co systems, A

307. Copper Alloy Tubes

An extensively illustrated 32-page brochure,
"Life Extension for Condenser Tubes", deals with
causes of corrosion and means of combating them, as well as choice of materials for condenser tubes.

Revere Copper & Brass, Inc.

308. Copper and Copper Alloys

New 24-page booklet B-36 discusses corrosive attack on copper and copper alloya. Includes tabulation for relative corrosion resistance of principal types of copper-base alloys. American

309. Cutting Oils

New bulletin on "Gulf Electro Cutting Oil", which contains larger percentage of active sulphur ingredient, recommended for toughest machining ingredient, recommendibles. Gulf Oil Corp.

310. Cutting Oils

Facts on more efficient and economical plant eration through use of right lubricants described "Metal Cutting Fluids" booklet. Cities Service

311. Cutting Oils

Send for your copy of Stuart's Shop Notebook, giving important facts on right cutting fluid for any machining operation. D. A. Stuart Oil Co.

312. Cutting Oils

Factual data on more than fifty typical metal-working jobs are presented in new 80-page edition of "Cutting and Grinding Facts". Also includes descriptions of straight and emulsifiable cutting oils with convenient chart for correct use. Sun Oil Co.

313. Dry Cooler

Bulletin DC-50 illustrates complete line of DriCoolers in a wide range of capacities and designs for specific cooling jobs. Marley Co.

314. Ductile Cast Iron

New list of publications available on advantages and properties of ductile iron, along with special applications and 100 authorized foundry sources now producing it. International Nickel Co.

315. Electrodes, Hard-Facing

Bulletin announcing completely new line of Wear-Arc hard-facing alloy electrodes. Includes full data on typical applications with physical properties, welding procedure and identification. Alloy Rods Co.

316. Electron Microscope

The new table model RCA electron microscope is described and illustrated in a 12-page booklet. Radio Corp. of America.

317. Finishes

New 4-page two-color bulletin describes in detail the entire line of Iridite finishes for nonferrous metals. Also includes section on APP process chemi-cals such as bright hardeners for zinc and cadmium plating and other specialties. Allied Research Products, Inc.

318. Forgings

New catalog 51 contains 30 pages covering such topics as type of forgings; where and how to use forgings; turnbuckle dimensions, strengths and related data. Well illustrated with tables and drawings. Merrill Box. Co.

319. Forgings

Technical bulletin 31 furnishes helpful informa-tion on stainless forging problems and includes specific data on chemical composition of alloy steels, Timken Roller Bearing Co.

320. Furnace

Full information furnished on new gas-at phere high-production furnace for handling b annealing of wire, strip and bar stock of copper nonferrous copper alloys. Holerali & Co.

321. Furnace, Atmosphere

Bulletin F-1 gives full description of vers controlled-atmosphere furnace for all steels high carbon to high speed in range 1200-280 Delaware Tool Steel Corp.

322. Furnaces

High temperature furnaces for temperature to 2000 °F are described in leaflet. Carl-M Corp.

323. Furnaces

New bulletin 84P describes eight sizes in grelectric models as well as conveyorized and hor pot-type furnaces. Desputch Oven Co.

324. Furnaces

Descriptive bulletins on salt pot furnaces wide range of sizes for either high or low-pre gas in heat treating small parts with lead, cya or other salt bath processes. Eclipse Fuel I

325. Furnaces

Complete "Buzzer" catalog available descri Buzzer high-speed gas furnaces designed prim for heat treating high carbon and alloy steels also atmospheric pot hardening furnaces for cyanide and lead hardening. Charles A. Hones

326. Furnaces, Industrial

6-page folder describes 18 typical installa of gas-fired and electric furnaces of various t complete with specially designed equipmen bright annealing, scale-free hardening, carbon toration, carborizing and production heat t ment. Electric Furnace Co.

327. Gas Analyzer

Further information available on Type 09-1 a new packaged unit vacuum fusion gas anal-used to determine the content of oxygen, nitr and hydrogen in metals. National Research (

328. Hardness Tester, Porta

Illustrated circular describing the Ames port hardness tester in sizes for work I inch to 6 in round and flat. Ames Precision Machine W.

329. Heating Elements, Electric

Bulletin H gives detailed information on AT-nonmetallic electric heating elements, inclu-tables for a wide variety of sizes available. Gl Div., Carborandum Co.

330. Heat Treating

Barrett standard anhydrous ammonia is a able in 150, 100 and 50-pound cylinders in veniently located stock points. Send for literat Barrett Div., Allied Chemical & Dye Corp.

331. Heat Treating

Ipsenlab periodic sheets show case histor bright hardening, annealing and carburizing. Industries, Inc.

332. Heat Treating

Bulletin 96 tells how Niagara Aero heat changers provide better heat treating by evapor cooling that controls temperatures, protects pl cal properties, and saves on water and pi equipment. Niagara Blower Co.

333. Heat Treating Carriers

Complete line of standard carburizing ca that will handle odd-shaped parts of every through carburizing and quenching to fini-Write for full information. Pressed Steel Co.

334. Heat Treating Equipme Bulletin 820 gives detailed description complete specifications on various size auton quenching tanks for use with continuous treating equipment. American Gas Furnace

335. Heat Treating Furnaces Illustrated literature describes newest deve ments in gas and electric heat treating furm Westinghouse Electric Corp.

336. Heat Treating Pots

New bulletin T-205 lists 118 patterns avail in Thermalloy heat treating pots, both round rectangular, X-rayed and pressure tested for so and economical service. Electro-Alloys Div.

337. High Speed Steel

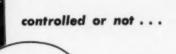
Full information on performance, heat tr ment and other authoritative facts furnisher booklet entitled "Molybdenum High Speed Stee Climax Molybdenum Co.

338. Immersion Heating

Bulletin IE-11 gives complete details on new immersion pots save time and money melting soft metals. High thermal efficiency both large and small units provides rapid recovery in one-third the time. C. M. R. Mfg. Co.

339. Induction Heating

Bulletin 1440 furnishes full details on "Checklite" system for safety control throug use of oversized components built into every for longer service life and uninterrupted produc



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Full information furnished on new gas-atmosphere high-production furnace for handling bright annealing of wire, strip and bar stock of copper and nonferrous copper alloys. Holcroft & Co.

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321. Ods Analyzer Further information available on Type 09-1240, a new packaged unit vacuum fusion gas analyzer, used to determine the content of oxygen, nitrogen and hydrogen in metals. National Research Corp.

328. Hardness Tester, Portable Illustrated circular describing the Ames portable hardness tester in sizes for work I inch to 6 inches round and flat. Ames Precision Machine Works.

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Barrett standard anhydrous ammonia is available in 150, 160 and 50-pound cylinders in conveniently located stock points. Send for literature. Barrett Div., Allied Chemical & Dye Corp.

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### What's New

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340. Induction Heating

For more economical manufacture in designing and redesigning present products, send for copy of "Design and or redesigning present products, send for copy of details on Technologies of the production of the details on Technologies of the details on Technologies of the details of the details

341. Industrial Planning

New book 127 tells how you can share in a "round-table" discussion of planning expansion, remodeling or modernization of your plant. Continental Industrial Engineers, Inc.

342. Industrial X-Ray

New catalog on "Industrial X-Ray Accessories" provides complete listing of this equipment, including chemicals, dark-room accessories, filing equipment, processing tanks, dryers and radiation instruments. Picker X-Ray Corp.

343. Insulation, Block

block insulation New 4-page folder on Superex block insulation tells economical advantages and lists outstanding properties by means of conductivity and heat loss graphs and recommended thickness table. Johns-

344. Iron, High Chromium

New booklet, "Abrasion-Resistant High-Chro-mium Iron", turnishes a complete sile of the best available information on how to make and use abrasion-resistant iron castings most efficiently. Electro Metallurgical Co.

345. Lab Furnaces

New pot furnaces for laboratory and research use are described in bulletina HD-635 and HD-546. Heri Duty Electric Co.

346. Laboratory Equipment

New literature ready on complete line of rapid carbon analyzers for steel, cast iron, pig iron, coal, coke, oil and cracking catalyst. Laboratory Equip-ment Corp.

347. Laboratory Safety

Newly revised edition of 40-page booklet includes recently developed data techniques and equip-ment, and provides useful manual for setting up-complete laboratory safety programs. Fisher Scientific Co.

348. Load Testing

Bulletin 325 describes new Type P SR-4 tension ad cells based on SR-4 bonded resistance wire rain gages for load measurement. Gives specifications for load cells of four capacities between 1000 and 100,000 pounds. Baldwin-Lima-swillow Core 1

349. Load Testing

Brochure 501 gives full details on universal testing machines in three ranges: Model TMU-A, 0-30,000, 0-6600, 0-600 lbs.; Model TMU-B, 0-15,000, 0-3000, 0-300 lbs. National Forge & Ordanace Company

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#### FACTURERS' LITERATURE

#### 350. Low-Melting Alloy

20-page manual on use of low-melting alloy in punch and die setting. Profusely illustrated. Cerro dePasco Corp.

#### 351. Magnesium Die Castings

Revealing book, "How Magnesium Pays", gives case studies of the economical uses of magnesium in a wide range of products. Dow Chemical Co

#### 352. Melting, Induction

8-page illustrated article describes use of induc-tion melting in improved technique for rotor-casting. Ajax Engineering Corp.

#### 353. Metal Analysis

Bulletin 220-F describes completely new mercury cathode, Dyna-Cath, that provides economical and high-speed separation of iron in determination of aluminum in steel. Eberbach Corp.

#### 354. Metal Cleaning

Information on new cleaning process that uses enusision cleaners, based on petroleum and addition agent 230. This two-phase bath provides unique cleaning in conjunction with a thin displacement film that removes foreign particles. Northwest Chemical Co.

#### 355. Metal Cleaning

New 44-page booklet. "Some Good Things to Knew 44-page booklet. "Some Good Things to Knew About Metal Cleaning", discusses wide variety of soils resulting from such metal-fabricat-ing jobs as head-treating, forging, rolling, the soil of the soil of the soil of the soil chining, buffing, etc., and describes specific mate-rials, equipment and procedures for their removal. Oakite Products, Inc.

#### 356. Metal Coating

Bulletin entitled "How To Obtain A Grade I Finish On Steel" furnishes full details on special protective coating required by Government Specification JAN-C-490, American Chemical Paint Co.

#### 357. Metal Finishing

New check list available on sixty products and processes for metal finishing, including a new acid addition agent, a cleaning and pickling agent com-bined, new complete inhibitor and a new rust preventive compound. Enthone, Inc.

#### 358. Metal-Forming Lubrication

New bulletin 426-B describes how colloidal graphite can solve your lubrication problems in metal-forming operations at temperatures from below zero up to 5000 F. Acheson Colloids Corp.

#### 359. Metal Hydrides

4-page folder on various hydrides of metals. Describes the use of these compounds in alloying, powder metallurgy and other metallurgical and chemical applications. Metal Hydrides, Inc.

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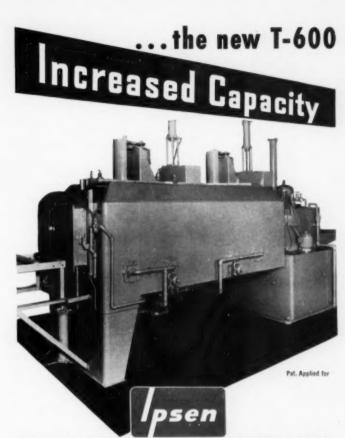
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PRECISION STEEL WAREHOUSE, N.C., 4435 W. Kinsie, Chicago - Phone: COlumbus 1-2700

## What's New

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#### 360. Metalworking Data File

Fingertip reference file contains engineering information about equipment and processes used for metal stampings, heavy weldments and pressed steel shapes. Chas. T. Brandt, Inc.

#### 361. Micrographic Equipment

Six-page bulletin on a universal camera micro-scope giving plate magnifications from 4 to 3000 X. Full details on optics and accessories included. Opplem Co.

#### 362. Microscopes

302. MICROSCOPES Well-illustrated 22-page booklet on Dynoptic Labroscopes, featuring ball bearings and rollers throughout the focusing system as well as low position fine adjustment with low controls that enable the operator to manipulate other controls more easily. Bausch & Lomb Optical Co.

#### 363. Midget Die Casting Machine

HIGHTHE

Illustrated folder describes new Kux Model K, small die casting machine, available in horizontal or vertical center shot models and capable of producing die castings weighing up to 1½ pounds in zinc under high injection pressures. Kux Machine Co.

#### 364. Nickel Silver

Paper dealing with detailed description of proper foundry procedure for production of sound castings from nickel silver. Also specification information. R. Lavin & Sons, Inc.

365. Oil Quenching
Catalog V-1146 gives detailed information on self-contained oil coolers, together with easy selection tables. Bell & Gossett Co.

#### 366. Organic Solvents

64-page handbook packed with information including hundreds of definitions, comparison tables, testing methods and product descriptions on a wide variety of organic solvents in common une. Pocket-size for easy reference. Solvents & Chemicals Group.

#### 367. Photomicrography

Full information furnished on Aristophot camera with Ortholux research microscope, providing the perfect team for easy, inexpensive photomicrog-raphy and photomacrography. E. Leits, Inc.

#### 368. Plating Barrels

4-page folder illustrates and describes the Daniels Plating Barrel designed to handle any barrel plating problem quickly and easily with a unique contact arrangement for maximum current distribution. Daniels Plating Barrel & Supply Co.

#### 369. Plating Generators

Catalog MP-700 describes M-G set for electro-plating, anodizing, electrocleaning, or electro-polishing in either large or small-scale operations. Columbia Electric Co.

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#### UFACTURERS' LITERATURE

370. Polishing and Buffing

Bulletin entitled "Acme Straightline Automatic Polishing and Buffing Machines" illustrates and describes a machine for every type of polishing and buffing job. Acme Mfg. Co.

371. Pyrometer

Catalog No. 165 describes improved Pyro surface pyrometer. Eight instruments in one. It handles all surface and sub-surface temperature measuring jobs. Pyrometer Instrument Co.

372. Pyrometer

New, general-purpose, low-temperature model, portable pyrometer now available as Type LT-840 Xactemp in a choice of four calibrations. Claud S. Gordon Co.

Quenching

For full information on the newest developments of Ajax isothermal heat treat process in martempering, austempering and other interrupted quenching operations, send for bulletin 120. Ajax Electric Co.

374. Quenching Oil

New technical bulletin F8 describes triple-action quenching oil. Accelerators provide deeper hardening and reduced distortion. Park Chemical Co.

375. Quench-Oil Cooler

10-page bulletin tells how cooling and circula-tion of quench oils assures control and saves time by continuous operation, in addition to reducing oil losees and fire hazards. Includes selection, capacity and dimension data. The Trane Co.

376. Reclaiming Process

Bulletin 330-D furnishes complete data on Engelhard Reclaiming Process, showing how on one 30" long platinum thermocupple it saved 53% compared with cost of new unit. Chas. Engel-hard, Inc.

377. Recording Meters
New 28-page bulletin 8-1111 describes Serie
Sop recording voltmeters and ammeters witl
special emphasis on newly-developed moving-iro
measuring mechanism. Complete data on ranges
and specifications of various models for permanen
and portable use. Brisid Co.

378. Refractories

40-page booklet, "Super Refractories for Heat Treatment Furnaces", gives recommendations for many specific types of furnaces. Carborundum Co.

379. Refractory

Form 1409 describes the new Norton Fused Stabilized Zirconia, ideal refractory for furnace thinings, metal melting, thermal insulation. Batts for firing Titanates and electric heater elements. Norton Co.

380. Refractory Mixes

Well-illustrated 16-page bulletin No. 315 provides important data on properties and applications of Sillimanite Super-Refractory ramming mixes and patches. Chas. Taylor Sons Co.

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381. Rust Preventive

New "How" book shows how slushing and degressing problems can be eliminated by Vapor-Wrapper method of packaging machines and parts. Nos-Rust Chemical Corp

382. Salt Baths

Valuable technical information available on heat treatment and molten salt bath operations. E. I. du Pout de Nemours & Co.

383. Soaking Pit

4-page technical bulletin with details on the onstruction and performance of new scaking pit which will reduce fuel consumption by 40% while almost doubling amount of steel heated. Loftus Engineering Corp.

384. Solder

36-page educational brochure on the properties and applications of solder. Profusely illustrated, with a resume of technical data and solder specifi-cations of ASTM, SAE, Federal and Military agencies. American Smelling br Refining Co.

385. Specimen Mount Press

New bulletin describing AB Speed Press. Fea-tures include use of preheated premolds, rapid closing and universal application for thermosetting or thermoplastic materials in 3 sizes. Backler Lid.

386. Spring Wire

Detailed information on Pittsburgh of tempered spring wire to help solve coiling, knotting, forming and twisting operation problems. Pittsburgh Steel Co.

387. Steel, Brake Die

For full information on top quality brake due of teel, engineered to machine easily and give long service, write for folder 560. Bethlehem Steel Co.

388. Steels, Low Alloy

You can have one-third more production through the use of Hi-Steel, which has nearly twice the working strength of ordinary steels plus the ability to stand up under impact loads. Send for booklet. to stand up und Inland Steel Co.

389. Steels, Low-Alloy Well-illustrated, 8-page folder on N.A.X low-alloy steels lists physical properties and test specifications. *Great Lakes Steel Corp.* 

390. Steels, Stainless

Weekly lists with analyses of all plates in stock will keep you regularly informed on latest data. G. O. Carlson, Inc.

391. Stud Welding Manual

New 32-page pocket-size Stud Welding Operating Manual available with step-by-step photographic explanation of actual stud welding process. K S M Products, Inc. Ma

392, Testing

New 30-page catalog on screw power universal testing machines and accessories includes illustrations and details of construction and specifications. Also information on special tools for different tests. American Machine & Meials, Inc.

393. Testing Machine

Bulletin 40 contains full details on the new low-cost Super "L" testing machine with Select-o-Range indicating system. Tinius Olsen Testing Machine Co.

394. Tool and Lab Furnace

New literature on hardening and tempering furnace designed to give automatic control of the entire temperature range from 300 to 2200 °F. K. H. Hupper Co.

395. Tool Steel

New booklet. "How to Get Hetter Tool and Die Performance", furnishes, full description of the matched set method for selecting the right tool steel for trouble-free production. Carpenter Steel Co.

396. Tubes, Bars, Steel

New stock list now available on 52100 tubing an bars as well as ring forgings. Peterson Steels, In.

397. Tubing

594. IUDING
For full information on analyses available, production limits, commercial tolerances, temper designations and product descriptions of Seamless and Weldrawn tubing, send for bulletin 32. Superior Tube Co.

398. Vapor Degreasing

Pamphlet on properties and use of trichlor-ethylene as a solvent for vapor degreasing of metal parts. Niagara Alkali Co.

399. Wear-Resistant Castings

New descriptive folder gives interesting facts on Colmonoy hard facing alloys, developed to combat different types of wear: abrasion, corrosion, impacted, Made in various forms to suit the methods of application. Wall Colmonoy Corp.

400. Welding, Oxy-Acetylene

16-page illustrated booklet traces the history of
oxy-acetylene flame and explains how industry is
using it today in cutting, welding, and heating
operations. Many specialized Jobs briefly described, such as hard-facing, flame-softening, flamehardening, powder-cutting and steel-conditioning.
Linda Air Products Co.





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SEPTEMBER 1951; PAGE 33

### What's New

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Paper dealing with detailed description of proper foundry procedure for production of sound castings from nickel silver. Also specification information. R. Lavin & Sons, Inc.

#### 365. Oil Quenching

Catalog V-1146 gives detailed information on self-contained oil coolers, together with easy selec-tion tables. Bell & Gossett Co.

#### 366. Organic Solvents

64-page handbook packed with information including hundreds of definitions, comparison tables, testing methods and product descriptions on a wide variety of organic solvents in common use, Pocket-size for easy reference. Notrents & Chemicals Group,

#### 367. Photomicrography

Full information furnished on Aristophot camera with Ortholux research microscope, providing the perfect team for easy, inexpensive photomicrog-raphy and photomacrography. E. Leits, Inc.

#### 368. Plating Barrels

4-page folder illustrates and describes the Daniels Plating Barrel designed to handle any barrel plating problem quickly and easily with a unique contact arrangement for maximum current distribution. Daniels Plating Barrel & Supply Co.

#### 369. Plating Generators

Catalog MP-700 describes M-G set for electro-plating, anodizing, electrocleaning, or electro-polishing in either large or small-scale operations. Columbia Electric Co.

#### 370. Polishing and Buffing

Bulletin entitled "Acme Straightline Automatic Polishing and Buffing Machines" illustrates and describes a machine for every type of polishing and buffing job. Acme Mfg. Co.

#### 371. Pyrometer

Catalog No. 165 describes improved Pyro sur-lace pyrometer. Eight instruments in one, it handles all surface and sub-surface temperature measuring jobs. Pyrometer Instrument Co.

#### 372. Pyrometer

New, general-purpose, low-temperature model, portable pyrometer now available as Type LT-840 Xactemp in a choice of four calibrations. Claud S. Gordon Co.

For full information on the newest developments of Ajax isothermal heat treat process in martempering, austempering and other interrupted quenching operations, send for bulletin 120. Ajax Electric Co.

#### 374. Quenching Oil

New technical bulletin F8 describes triple-actic quenching oil. Accelerators provide deeper have ening and reduced distortion. Park Chemical C

#### 375. Quench-Oil Cooler

10-page bulletin tells how cooling and circula-tion of quench oils assures control and saves time by continuous operation, in addition to reducing oil losses and fire hazards. Includes selection, capacity and dimension data. The Trane Co.

#### 376. Reclaiming Process

Bulletin 330-D furnishes complete data on Engelhard Reclaiming Process, showing how on one 30" long platinum thermocouple it saved 53% compared with cost of new unit. Chas. Engel-hard, Inc.

New 28-page bulletin E-1111 describes Series S00 recording voltmeters and ammeters with special emphasis on newly-developed moving-iron measuring mechanism. Complete data on ranges, and specifications of various models for permanent and portable use. Brisid Co.

#### 378. Refractories

40-page booklet, "Super Refractories for Heat Treatment Furnaces", gives recommendations for many specific types of furnaces. Carborundum Co.

#### 379. Refractory

Form 1409 describes the new Norton Fused Stabilized Zirconia, ideal refractory for furnace linings, metal melting, thermal insulation. Batts for firing Titanates and electric heater elements. Norton Co.

#### 380. Refractory Mixes

Well-illustrated 16-page bulletin No. 315 pro-ides important data on properties and applica-ions of Sillimanite Super-Refractory ramming nixes and patches. Chas. Taylor Sons Co.

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#### METAL PROGRESS

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381. Rust Preventive

New "How" book shows how slushing and degreasing problems can be eliminated by Vapor-Wrapper method of packaging machines and parts.

Noz-Rust Chemical Corp.

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Valuable technical information available of heat treatment and molten salt bath operation E. I. duPont de Nemours & Co.

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4-page technical bulletin with details on the onstruction and performance of new soaking pit which will reduce fuel consumption by 40% while almost doubling amount of steel heated. Leftus Engineering Corp.

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#### 390. Steels, Stainless

Weekly lists with analyses of all plates in stock will keep you regularly informed on latest data. G. O. Carlson, Inc.

#### Stud Welding Manual

New 32-page pocket-size Stud Welding Operating Manual available with step-by-step photographic explanation of actual stud welding process. K S M Products, Inc.

#### 392. Testing

New 30-page catalog on screw power universal testing machines and accessories includes illustra-tions and details of construction and specifications Also information on special tools for different tests American Machine & Metals, Inc.

#### 393. Testing Machine

Bulletin 40 contains full details on the new low-cost Super "L" testing machine with Select-o-Range indicating system. Tinius Otsen Testing Machine Co.

394. Tool and Lab Furnace

New literature on hardening and tempering furnace designed to give automatic control of the entire temperature range from 300 to 2200 °F. K. H. Happett Co.

#### 395. Tool Steel

New booklet, "How to Get Retter Tool and Die Performance", furnishes full description of the matched set method for selecting the right tool steel for trouble-free production. Carpenter Steel Co.

#### 396. Tubes, Bars, Steel

New stock list now available on 52100 tubing and bars as well as ring forgings. Peterson Steels, Inc.

For full information on analyses available, production limits, commercial tolerances, temper designations and product descriptions of Seamless and Weldrawn tubing, send for bulletin 32. Superior Tube Co.

#### 398. Vapor Degreasing

Pamphlet on properties and use of trichlor-ethylene as a solvent for vapor degreasing of metal parts. Niagara Alkali Co.

#### Wear-Resistant Castings

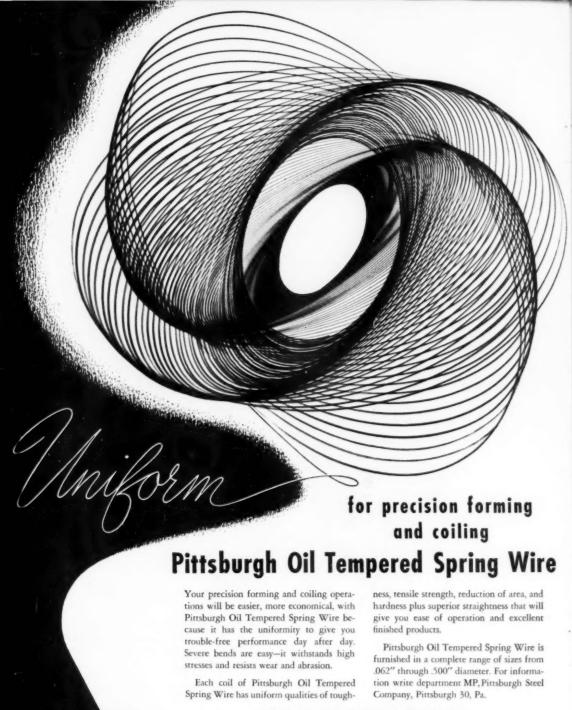
New descriptive folder gives interesting facts on Colmonoy hard facing alloys, developed to combat different types of wear: abrasion, corrosion, impact, etc. Made in various forms to suit the methods of application. Wall Colmonoy Corp.

#### 400. Welding, Oxy-Acetylene

16-page illustrated booklet traces the history of oxy-acetylene flame and explains how industry is using it today in cutting, welding, and heating operations. Many specialized jobs briefly described, such as hard-facing, flame-softening, flame-hardening, powder-cutting and steel-conditioning. Linde Air Products Co.



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The Steel Industry Needs Scrap-Keep it Moving

## Pittsburgh Wire

a product of Pittsburgh Steel Company



- Generous Sized Cabinets
- Conditioned Cooling System
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- Filament Voltage Regulation
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Filament Voltage regulation essures maximum tube life-voltage regulators maintain filament voltage at proper values regardless of line voltage fluctuationsthus, tubes operate under ideal conditions.

Tough . . . rugged . . . with the stamina of champions! Lindberg Induction Heating Units, like the six-day bike racers of old, grind away at their jobs-24 hours a day, day after day . . . and still have a strong reserve for those vital sprint finishes that occur in metal working as in sports.

Yes... Lindberg Induction Heating Units are built for heavy production line servicefar beyond the usual capabilities of induction heating equipment. Investigate the Lindberg Induction Heating Units. You will profit from their rugged ability to deliver 24 hour a day operation. Ask for Bulletin 1440.



LINDBERG of HIGH FREQUENCY DIVISION



Lindberg Engineering Company, 2448 W. Hubbard Street, Chicago 12, Illinois

## **New Development in Salt Baths**

## Eliminates scale and decarburization on steels in neutral salt baths operating up to 2300° F.

NEUTRAL hardening in molten salt baths should mean just what it says. No scale or decarburization is present in a properly rectified neutral salt, regardless of temperatures used. This is possible at 1500°F. and up to 2300°F. A recent development by one of the leading salt bath suppliers makes this possible for the first time without the manual addition of solid deoxidizers. The Neutra-Gas Process (U. S. Patent No. 2474680) is simple, effective, and inexpensive. Merely bubble an inexpensive commercial gas through the molten bath for recommended periods. Neutrality is easily checked chemically or physically. The Neutra-Gas Process is operating at the present time in molten baths weighing less than 100 pounds and those holding several tons of salt.

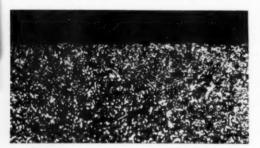
A truly neutral salt is the ideal medium for heating all steels with no surface effect. There is no atmosphere, and air is excluded while the work is heating. Scaling and decarburization are prevented. A thin film of salt protects parts right up to the quench. With neutral salts operating at 1500°-1600° F., Neutra-Gas is used for just a few minutes per shift. Sludging is practically eliminated; economies result because sludging removes good usable salt. The bath remains very fluid allowing rapid and uniform heating with less distortion. To obtain all the advantages of salt bath hardening, use salt baths for both heating and quenching. The improved fluidity of the Neutra-Gas controlled neutral salt assists materially in isothermal quenching salt operations.

#### Neutral Salts from 850° - 1850°

Various salt mixtures provide a wide range of usefulness in the heat treatment of steel. The Neutra-Gas is used with chloride mixtures only. The most popular type is Park Nu-Sal Neutral Salt. Its melting point is 1230°F, with a range of 1300°-1600°F. Most steel hardening temperatures fall within this range. Nu-Sal is widely used as the austenizing bath for isothermal treatments such as austempering and martempering.

Cycle annealing involves a wider range of temperatures. Park K-3 Neutral Salt melts at 1020°F, and is usable past 1700°; periodic use up to 1850° is permitted if proper rectification is made with Neutra-Gas.

Low melting salts are available for special purposes. Park's #800 Neutral Salt (melting point 850°F.) and Park



(X 500) Microphotograph of the edge structure on SAE 1095 steel treated for 60 minutes at 1450°F. in a commercial installation of Park Nu-Sal kept neutral with the Neutra-Gas process. (Sample quenched in caustic solution and tempered in No. 800 Neutral Salt at 1200°F.)

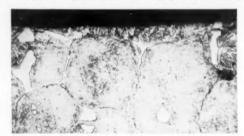
#900 Salt (melting point 920°) are used for tempering, high speed steel quenching, and have a range up to 1700°F.

Baths operating consistently at 1700° to 1900°F. usually operate with less fuming and volatilization if their melting points and top operating temperatures are slightly higher. Park K-17, with a range up to 1900°F., also has a reasonably low melting point of 1175°F. Economy is indicated here as the temperature of an idle furnace may be kept at 1250°-1300° with very low power costs.

#### No Decarb on Moly High Speed Steels

Wider use of molybdenum high speed tool steels has virtually made the use of salt baths mandatory. During the last War it was salt baths which made possible the adoption of the molybdenum high speed steels in place of the very critical tungsten types.

As in most instances, the increased use of a method leads to rapid improvements. The improved rectification of high heat salt baths operating from 2200°-2300°F. is a development of the Park Chemical Company laboratories. The Neutra-Gas Process was adapted to the higher temperature applications in order to reduce the oxides of the chloride salts. Metallic oxides are reduced by graphite rods immersed in the salt. Costly and laborious sludging has been nearly

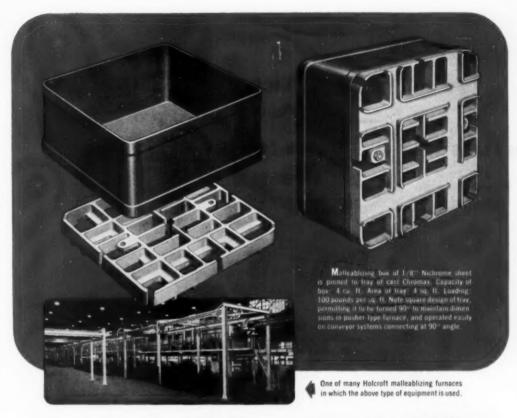


X500—(Reduced in Printing) Edge structure of high speed steel after several hours in a Park No. 175 Hi-Heat salt bath.

eliminated and electrode life increased. Size loss of tools is held to a minimum. It is possible to harden unground or finished tools. Scaling, decarb, oxidation, pitting and other surface defects are automatically avoided. Distortion is negligible. Immersion in salt seals out all atmosphere. Salt film protects work right through the quench. For pieces large or small, temperature is even and constant.

Process detail is preheat at 1550°F, in Park No. 117 Preheat Salt, high heat at 2200°-2350°F. in Park High Heat No. 175-S with Neutra-Gas. Quench in either No. 900 Neutral Salt, or in No. 100 Quench Salt which contains a small amount of cyanide. Tempering in salt completes the cycle, free from any deleterious effect caused by contact with the atmosphere.

Park's salt baths, and the knowledge of how to make them do a better job for you, can effect economies in your heat treat department. Write, telling us in detail your application, and we will send you the technical bulletin that covers your particular operation. There is a Park field engineer to assist you, backed by a technical staff and 40 years of Park Chemical Co. service to the heat treating industry. Park Chemical Company, 8074 Military Ave., Detroit 4, Michigan.



## **How Live Load Ratio was improved 250%**

A large midwestern implement foundry has proved that use of trays and boxes made of Driver-Harris alloys, for malleable annealing of small parts, results in outstanding savings in deadweight and better heat transfer. Production has been stepped up considerably by increasing live load and shortening the heat-treating cycle.

Hard cast iron boxes, formerly used in tunnel kilns, weighed 650 pounds each, and carried a maximum work load of 330 pounds-giving a load ratio of approximately 0.5 to 1.

Boxes in service today are fabricated from 1/8" Nichrome® sheet. These are pinned to specially designed trays of cast Chromax\* (see illustration). Box load is 400 pounds. Total weight of a box and tray is 180 pounds. Thus load ratio is 400 to 180, or approximately 21/4 to 1.

Such a remarkable improvement in the ratio of live load to deadweight of containers (almost 250%) has, of course, resulted in proportionate improvement in efficiency-or fuel saving.

To date, these boxes and trays have given 36 months of service in a continuous malleablizing furnace. During this period, they have made 480 trips through the furnace-representing 480 heat and cool cycles. They have been in the furnace 22,640 hours, about 86% of the total elapsed time, under temperatures up to 1725°F. Each box has annealed 90 tons of work.

Neither boxes nor trays are showing any permanent distortion or embrittlement. In fact, they are performing as well today as when first put into service, and are proving conclusively that malleable annealing can be a clean, labor-saving, fuel-saving operation.

Here is but another example of how Driver-Harris alloys are being applied to great advantage in the heat-treating field. Why not consult with us for a solution to your heat-treating equipment and furnace part problems? Although the demand for D-H products in the present emergency is engaging the resources of this firm to an unprecedented extent, we shall be glad to serve you to the best of our ability.



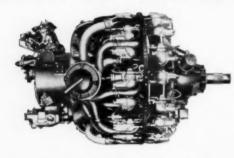
Nichrome and Chromax are manufactured only by

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#### HELPS HARNESS THE "CYCLONE"



• Each new Wright 18-compound "Turbo-Cyclone" aircraft engine puts 3250 horsepower roaring into action. Helping convert that tremendous power into flashing aircraft performance is this turbine shaft, precisely machined from ENDURO Stainless Steel.

ENDURO serves the aircraft power plant designer and producer well. Free-machining ENDURO bars—both hot rolled and cold drawn—economically pair exceptional resistance to heat, abrasion and corrosion with great strength and durability.

ENDURO responds readily to forging. As this shaft indicates, it is readily machinable. Two ENDURO grades, for example, are fully 90% as machinable as Bessemer screw stock. In cold finished bar form, ENDURO provides close tolerances, accuracy of section, uniform soundness, and fine surface finish.

Need help in harnessing too-high machining costs in your own stainless steel parts? The combination of free-machining ENDURO and competent Republic metallurgical help has held costs down for many a manufacturer. Write:

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Other Republic Products include Carbon and Alloy Steels-Pipe, Sheets, Strip, Plates, Bars, Wire, Pig Iron, Bolts and Huts, Tubing

## "Tool life on Inconel rivets up 35% with Gulf Electro Cutting Oil"



"Because we specialize in tough machining jobs, we know that there's a big difference in cutting oils," says this General Manager. "On Inconel aircraft rivets, for example, we get much better results with Gulf Electro Cutting Oil. Production is up 35%, and tool life is excellent:

Form & cut-off tools—500-600 pieces per grind Carboloy box tools—800 pieces per grind Center spotting tool—500-600 pieces per grind

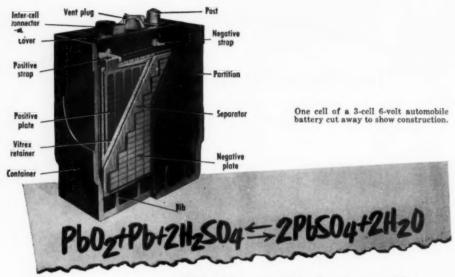
Here's the important reason why Gulf Electro Cutting Oil delivers such outstanding performance. Thanks to a special Gulf process of combining sulphur, it provides greater sulphur activity over the entire range of a cutting operation. This intensified chemical action means better protection for the tool at elevated production rates—helps reduce built-up edge, prevents chip welding, prolongs tool life.

Operators like it because they get these production advantages without the disagreeable odor ordinarily associated with sulphurized cutting oils.

Call in a Gulf Lubrication Engineer today and arrange to use this outstanding oil in your shop, or send the coupon below for additional information.



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## this electrochemical reaction accounts for the largest use of lead!

The operation of the modern storage battery is based on a familiar electrochemical principle first applied in 1800 by Volta: Two unlike metals, or unlike forms of the same metal, separated by a porous non-conductive material will, when immersed in an electrolyte, cause an electric current to pass through an external connecting circuit.

The plates of the storage battery are dissimilar forms of lead; the electrolyte is dilute sulfuric acid. The chemical reactions taking place in a storage battery are shown in the diagram at right, and are also expressed as an equation in this advertisement's heading. Reading from left to right, the equation shows the reactions involved in discharge. Passing an electric current through the battery in a direction opposite to that of discharge reverses the action. Read from right to left, the equation thus shows the reactions involved in charging.

Electrical energy in the battery is produced as a result of changing one atom of metallic lead and one molecule of lead peroxide into two molecules of lead sulfate. The metallic lead loses two electrons which convert the lead peroxide to lead sulfate. It is the transfer of these electrons in the circuit which causes the flow of current. The manufacture of battery plates has, for many years, consumed about one-third of all the lead used in the United States. The choice of materials for the storage battery's major elements was based on the following premises: The chemical reaction it volved had to be a reversible one so that the battery could be recharged. The materials had to be abundant in nature, available for use in large volume; they had to be resistant to attack by the electrolyte and so related to each other in the electrochemical series as to present the greatest potential (voltage) difference.

Lead meets all these exacting requirements excellently. Of the common metals, it has the highest resistance to

## ST. JOSEPH LEAD CO.

THE LARGEST PRODUCER OF LEAD IN THE UNITED STATES

sulfuric acid. It is relatively abundant in nature and moderate in cost. It is one element which occurs in two chemical valences and thus provides a relatively high potential difference (2-volts). Last, but not least, around 85% of the close to 300,000 tons of lead used annually in the manufacture of batteries is reclaimed within 2 or 3 years and returned to the market. This use of lead is therefore recurrent and plays a key role in the conservation of the nation's mineral resources.

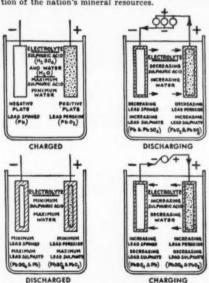


Diagram showing essential action in storage battery. Courtesy: The Electric Storage Battery Co.

### From Bumper to Tallgate ... Reduces Deadweight and Increases Durability HIGH-TENSILE STEEL The widespread use of N-A-X HIGH-TENSILE steel in transportation equipment emphasizes two vital characteristics of this high-strength low-alloy steel. 1. Strength with less deadweight. N-A-X HIGH-TENSILE steel reduces deadweight . . . of great importance in transportation equipment and military vehicles. 2. Exceptional durability. N-A-X HIGH-TENSILE steel, with its high strength and toughness, has proved greater resistance to fatigue and impact at normal and sub-zero temperatures. Its inherent structure and composition greatly reduce the effects of abrasion and corrosion. The response of N-A-X HIGH-TENSILE steel to severe cold-forming operations and its excellent weldability by electric are or resistance, atomic hydrogen or heliare, and all other processes, are added important characteristics of N-A-X HIGH-TENSILE steel. SCRAP The "Eager Beaver" The use of low-alloy, highstrength steels in military equipment assures longer life with less deadweight. EAT LAKES STEEL CORPORATION

NATIONAL STEEL CORPORATION

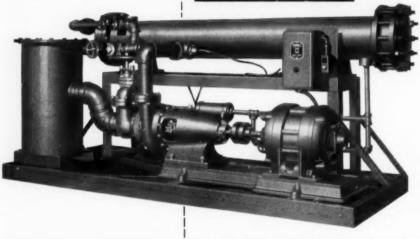
## Controlled Quenching... **Expertly Engineered**

WE SURVEY... A B & G representative, in consultation with your engineers, examines your plant layout and determines what results are desired in your heat treating department.

WE ENGINEER... From data accumulated in your plant, the B&G engineering staff designs a complete quench-oil system, tailored to your specific requirements.



YOU RECEIVE... A complete recommen dation as to size and type of equipment needed is delivered to you promptly. The only remaining step is to install the





BAG SERIES 1522 PUMP ne unit of a complete line of centrif-al pumps—catalog on request.

The quenching stage of your heat-treating process is the point where all previous operations are brought to either a successful or unsatisfactory conclusion.

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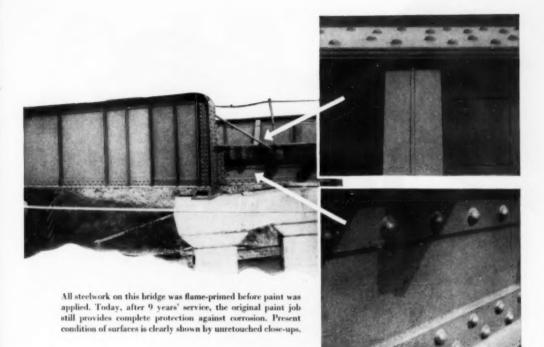
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METAL PROGRESS; PAGE 42



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help HOOVER to cut diecasting costs by efficient melting and pumping of Aluminum

CASE HISTORY

COMPANY: The Hoover Company, Kingston-Conley Division, Cambridge, Ohio, plant.

PROBLEM: To conserve scarce copper supply by use of aluminum as a substitute.

To cut die-casting costs in the manufacture of squir-

rel-cage induction motor rotors without sacrificing performance characteristics.

Fig. 1 shows notate of DESTHATE

AJAX electromagnetic pump discharging metal into cold chamber of diecasting machine.

Fig. 2 shows AJAX melting furnace and electromagnetic pump installed in front of die-casting machine.

Pig. 3 shows Hoover squirrel-cage aluminum cast rotors.

SOLUTION: Installation of the LOEWY-HYDROPRESS die-casting system, in which several sizes with various end ring designs are made in same die by simple change of inserts.

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AJAX ELECTRO METALLURGICAL CORP., and Associated Companies AJAX ELECTROTHERMIC CORP., Apa Northup high freezeng induction lumaxis AJAX ELECTRIC CO., INC., The Agas Hulgern Electric Saft Eath Funnace AJAX ELECTRIC FURNACE CORP., Apa Wyat Induction Funnaces for Method

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## Metal Progress

Vol. 60, No. 3 · September 1951

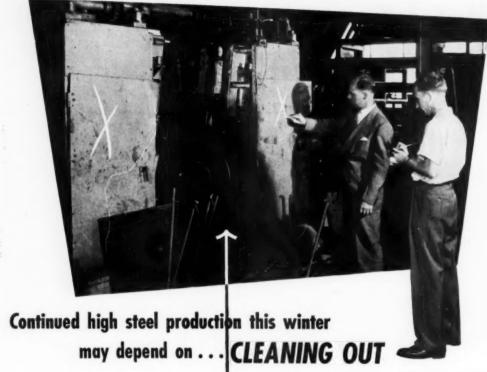
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METAL PROGRESS; PAGE 50

## Titanium in Aircraft

THE UNITED STATES AIR FORCE became acutely aware of the dependence of large-scale aircraft production on a continuous supply of raw materials in 1942 and 1943 when a shortage of aluminum appeared imminent. The supply of South American bauxite had been reduced to a trickle. Fortunately, ore supply was supplemented by the increased production and beneficiation of lower grade domestic ores, and castings, rolled, extruded and other forms were made available by the construction of new plants and improved allocation of available products. The possibility of even greater demands on this country's mineral resources was envisaged, and immediately upon cessation of hostilities the Air Force sponsored a survey of the resources in continental North America. Its purpose was to investigate metals obtained from these minerals which might replace or augment those in short domestic supply.

One of the metals which gave promise of meeting the requirements for a structural material for aircraft and engines was titanium. The principal ores, rutile and ilmenite, occur rather

abundantly in accessible deposits near the St. Lawrence in Quebec; Canada's total reserves of titanium metal are estimated at 105,000,000 tons. Virginia, New York, Wyoming, Florida and North Carolina have proven ore deposits in that relative order of importance; estimated metal in these deposits amounts to 5,400,000 tons,

The titanium metal reserves on the continent are, therefore, equal to more than 100 years' supply at the maximum production rate for aluminum reached during the war. The mining and smelting of titanium-rich ores had been developed on a large scale for paint pigments. In fact, the production of titanium dioxide in 1946 closely paralleled the maximum production of alumina before the war. Titanium could thus be classified as a "nonstrategic" metal, when measured by the yardstick of the availability of domestic ores.

Wilhelm Kroll and the staff of the U. S. Bureau of Mines had developed a process for the production of ductile titanium in 1940. Briefly, the method consists of the reduction of titanic chloride to titanium sponge with an excess of magnesium in a helium atmosphere at about 1550°F. The excess magnesium is then dissolved in hydrochloric acid, and wrought products made from sintered compacts of the

resulting titanium powder. The forging and rolling characteristics, corrosion resistance, and mechanical properties were favorable. Battelle Memorial Institute, under a RAND contract of the United States Air Force, also investigated are-melting procedures for this powder and were successful in producing titanium and titanium alloy ingots. This process has been successfully adapted to commercial production. Several well-organized firms are now in the business, and a limited amount of titanium alloys made by various techniques is available for test and small-scale use.

Strength-to-Weight Ratio — An engineering material must have structural efficiency to give satisfactory service. The primary consideration is, generally, adequate mechanical properties, but in aircraft applications weight also controls efficiency and the strength-to-weight ratios are always referred to in any discussion concerning the comparative merits of different metals.

For comparison, the strength properties of light aircraft structural sheet materials at several temperatures are listed in Tables Ia and Ib.

The ratios, which are the uni-axial stresses in tension (or compression) divided by unit weight, actually rate the materials when they are used in components subjected to tensile loads (or to block compression loads with-

out buckling). The relative magnitude of the tensile strength-weight ratios are displayed in Fig. 1 so the materials can be visually compared at each of the three temperatures.

If the metals are evaluated as to ability to resist column buckling or plate buckling, the order may be somewhat different. However, there are many examples of aircraft components, such as wings, fuselages and control surfaces, which have been fabricated from either high-tensile Type 304 stainless steel (18-8), 24S-T aluminum alloy, or AZ31X magnesium

and E. J. Nassell\*

Metallurgy Group

Wright-Patterson A. F. Base
Dayton, Ohio

By J. B. Johnson\*

\*Mr. Johnson is chief and Mr. Hassell is metallurgist in the Metallurgy Group, Flight Research Laboratory, Wright Air Development Center, Wright-Patterson Air Force Base.

Table Ia — Strength of Aircraft Structural Metals at 70° F.
First five lines from ANC-5a "Strength of Metal Aircraft Elements", 1949

|                                         | D                          |                          | COMPRI                          | COMPRESSION                  |                           |      |      |                             |        |
|-----------------------------------------|----------------------------|--------------------------|---------------------------------|------------------------------|---------------------------|------|------|-----------------------------|--------|
| METAL                                   | DENSITY<br>d<br>LB./Cu.In. | Modulus<br>E<br>106 Psi. | $\frac{\mathbf{E}}{\mathbf{d}}$ | ULTIMATE<br>T.S.<br>103 Psi. | YIELD<br>Y.S.<br>103 Pst. | T.S. | Y.S. | YIELD<br>C.Y.S.<br>103 Psi. | C.Y.S. |
| Type 304 stainless steel<br>(full hard) | 0.286                      | 26.0                     | 90                              | 185                          | 140                       | 647  | 490  | 105                         | 367    |
| Type 347 stainless steel                | 0.200                      | 20.0                     | 30                              | 100                          | 140                       | 047  | 4.00 | 100                         |        |
| (annealed)                              | 0.286                      | 29.0                     | 101                             | 75                           | 30                        | 262  | 105  | 35                          | 122    |
| Aluminum alloy                          |                            |                          |                                 |                              |                           |      |      |                             |        |
| 24S-T4 (bare)                           | 0.100                      | 10.5                     | 105                             | 68                           | 51                        | 680  | 510  | 42                          | 420    |
| Aluminum alloy                          |                            |                          |                                 |                              |                           |      |      |                             |        |
| 75S-T6 (bare)                           | 0.101                      | 10.3                     | 102                             | 82                           | 72                        | 810  | 710  | 72                          | 710    |
| Magnesium alloy                         | 0.0045                     | 0.5                      | 101                             | 20                           | 00                        | 200  | 1=0  | 0.4                         | 372    |
| AZ31 X<br>Titanium metal                | 0.0645                     | 6.5                      | 101                             | 39                           | 29                        | 600  | 450  | 24                          | 3/2    |
| (annealed) *                            | 0.163                      | 15.0                     | 92                              | 80                           | 70                        | 490  | 430  | 70                          | 430    |
| Titanium alloy                          | 0.103                      | 10.0                     | 32                              | 00                           | 70                        | 430  | 400  | 10                          | 400    |
| RC-130 A†                               | 0.163                      | 16.0                     | 98                              | 150                          | 130                       | 920  | 800  | 135                         | 827    |
| Experimental titanium                   |                            |                          |                                 |                              |                           |      |      |                             |        |
| alloy‡                                  | 0.163                      | 16.0                     | 98                              | 190                          | 170                       | 1160 | 1040 | 170                         | 1040   |

\*"Technical Information on Titanium Metal", Remington Arms Co., Inc.

†Data from Rem-Cru Titanium Co.

‡"Research and Development on Titanium Alloys", Battelle Memorial Institute.

alloy to meet the same static and dynamic load requirements. On test, these assemblies supported equal loads and the weights were the same, within production tolerances. When the ratios of modulus to density are approximately equal (90 to 105, as in Table I), the ratios of uni-axial allowable stress to density can be assumed to indicate an accurate rating for alternate materials when applied to complete assemblies, even though the several details on parts in these assemblies may be designed to carry a combination of tension, compression, shear and buckling loads.

This analysis would indicate that a variation of less than 100 in the ratio T.S./d is not too significant, since the three metals noted above fall within the range of 600 to 680 at room temperature (Table Ia); a difference of over 100, however, is significant. For example, components originally fabricated from 24S-T with T.S./d = 680 have been redesigned using 75S-T with T.S./d = 810, and weight savings have accrued. The lower rating of commercially pure titanium at room temperature (T.S./d = 490) as an alternate for the basic structural metals, 75S-T, 24S-T. Type 304 stainless, and AZ31X, is illustrated in Fig. 1.

The comparison of commercial titanium with annealed Type 347 stainless steel (18-10, stabilized) is favorable, and most of the present applications of this grade of titanium have been

made on a volume-for-volume substitution and, consequently, with an appreciable reduction in weight of the component. This usage is quite restricted and affects only a small percentage of the total airframe weight. It is confined, generally, to those parts operating at temperatures above 250 to 300° F. The advantage is maintained at 300°, but practically nullified at 700° F.

Type 304 stainless (18-8) has a more favorable position in the series of alloys when appraised at 300 and 700° F., but this may be somewhat misleading since the higher mechanical properties are due to cold work and the values in Fig. 1 are taken from short-time elevated temperature tests. Comparison on the basis of data for stress-rupture tests for long periods would probably show a greater decrease for the Type 304 stainless as compared to titanium.

Experimental Titanium Alloys — Titanium alloys have considerably higher ratings at all three temperatures. This fact and the high corrosion resistance have generated a great deal of interest in titanium-base alloys in the aircraft industry. Titanium alloy RC-130A was selected as representative of several available alloys now in production with similar properties. An alloy with these mechanical properties is useful for many statically and dynamically loaded parts in airframes and engines where the operating temperatures do not exceed 700 to 800° F.

Table Ib - Strength of Aircraft Structural Metals at 300 and 700° F.

| Т                                        | ESTS AT 300                | 0° F. |      | Т                                        | ESTS AT 70               | 0° F. |      | A.M.S.                                                              |       |
|------------------------------------------|----------------------------|-------|------|------------------------------------------|--------------------------|-------|------|---------------------------------------------------------------------|-------|
| ULTIMATE<br>T.S.<br>10 <sup>3</sup> Psi. | YIELD<br>Y. S.<br>103 PSI. | T.S.  | Y.S. | ULTIMATE<br>T.S.<br>10 <sup>3</sup> Psi. | YIELD<br>Y.S.<br>103 PSL | T.S.  | Y.S. | METAL                                                               | Spec. |
| 146 (b)                                  | -                          | 510   |      | 128 (b)                                  | -                        | 445   |      | Type 304 stainless steel<br>(full hard)<br>Type 347 stainless steel | 5519  |
| 75 (c)                                   | 34                         | 260   | 120  | 67 (c)                                   | 32                       | 235   | 110  | (annealed)                                                          | 5512  |
| 10.41                                    |                            | 100   | 0.70 |                                          |                          |       |      | Aluminum alloy                                                      |       |
| 42 (d)                                   | 37                         | 420   | 370  | 5                                        | 3.5                      | 50    | 35   | 24S-T4 (bare)<br>Aluminum alloy                                     | 4037  |
| 25 (d)                                   | 22                         | 250   | 220  | 6.5                                      | 5                        | 65    | 50   | 75S-T6 (bare)                                                       | 4045  |
| 22 (d)                                   | 13                         | 340   | 200  | 4                                        | 2                        | 60    | 31   | Magnesium alloy<br>AZ31 X                                           | 4376  |
| 60                                       | 42                         | 370   | 260  | 36                                       | 20                       | 220   | 120  | Titanium metal<br>(annealed)                                        | _     |
| 125                                      | 100                        | 760   | 610  | 100                                      | 70                       | 615   | 430  | Titanium alloy<br>RC-130 A                                          |       |
| 160 (e)                                  | 130                        | 980   | 790  | 125                                      | 90                       | 760   | 550  | Experimental titanium alloy                                         |       |

(a) Aeronautical materials specification of Society of Automotive Engineers.

(b) Calculated from shear properties at elevated temperatures. See "Nickel Alloy Steels", 2nd edition, 1949, International Nickel Co., Inc.

(c) "Steels for Elevated Temperature Service", United States Steel Co.

(d) High-temperature properties from "A.S.M. Metals Handbook", 1948 edition.

(e) High-temperature properties estimated from corresponding values for RC-130A.

It is also possible that an alloy of aluminum will be developed which will have a strength-weight ratio at room temperature equal to or higher than titanium alloy RC-130A. Unfortunately, the strong alloys of the aluminum-zine-magnesium ternary system lose

strength rapidly with increasing temperature. Since this system has produced the alloys having the highest mechanical properties at room temperature, it will be necessary to develop another system if aluminum alloys are to be used in structures working at elevated temperatures.

The titanium alloy referred to as "experimental" in Table I is representative of several which have been produced in the laboratory in the form of rolled strip. Their ductility (as measured by elongation and bend tests) is low, and the ratio of yield strength to tensile

strength is high—both factors which increase the difficulties in forming unless the alloys are amenable to annealing for softening, and subsequent hardening after forming. Many constitutional diagrams for binary alloys have been determined in the high-titanium region, and the

Fig. 1 - Comparison of Strength-Weight Ratios of Various Metals Used in Aircraft Structures ROOM 300° F 700° F **TEMPERATURE** TENSILE STRENGTH YIELD STRENGTH DAYA STRENGTH DISTA 9 AZ 31 X Comm. Ti. 104 5.5.

possibility of heat treating to improve the tensile strength is not attractive, but sufficient work has been done on ternary and more complex titanium alloys to warrant considerable optimism that a high-strength production alloy will be developed. The problems to be surmounted are similar (for the most part) to those previously solved in the production and utilization of alloys of other metals.

#### COMMERCIAL DEVELOPMENT

"Titanium melts at a high temperature (3150° F.) and, when molten, reacts with virtually everything it touches. Some gases and metallic elements have important effects when present in the solid metal; for instance, small amounts of oxygen and nitrogen decrease the ductility markedly. Furthermore, specimens prepared by sintering and those made by melting may differ considerably in their properties. But after all due allowances are made for present uncertainties, titanium is still a light, strong, ductile, corrosion resistant metal whose structural applications will depend largely on getting the cost of the metal down from its present high level of \$5 a pound. Just how soon titanium will come into widespread industrial use will depend also on the development of titanium alloys for specific purposes. Considerable progress in alloying is reported, and serviceable titanium alloys are in prospect, both for use at normal and at elevated temperatures."

The above quotation from the March 1949 issue of Metal Progress, a foreword to a series of articles on titanium and titanium alloys, fits the situation today as well as it did then. The demand for commercially pure titanium, either for aircraft or other engineering applications,

will not be sufficient to build up a large producing industry. Alloys must be developed for specific purposes. The successful alloys will be those which can be used by engineers to improve the performance of a machine or structure, increase its life, or show some other tangible gain for the money expended. Titanium alloys are expensive; it may be that the aircraft industry can pay more per pound for a desirable material, but in the final analysis that material must still earn its keep.\*

A survey of past history indicates that no new material completely replaces all other materials in an aircraft structure. The new one is first used with considerable caution and for a few components where the largest weight savings are evident. It requires from five to seven years to get a new structural material with proven superior properties into production in airplanes or engines in relatively large quantities—and by that is meant more than 5 to 10% of the total weight.

Titanium has become part of the rearmament program and the time factor in its utilization may be reduced by accelerating the development of new reduction processes for sponge, and of better melting practices and fabricating procedures in mill and factory. All of these will doubtless result from the large funds being expended by private industry and the government. Currently, the very small commercial usage is an offsetting factor. It is doubtful if the demand for munitions alone can create a very large producing industry. Commercial usage in peacetime products is essential. This requires not only a competitive price with other materials, including a good scrap market. but also continuous output of engineering data on forming, machining, joining, and finishing

production is measured in tons instead of pounds annually, by drawing a parallel with magnesium and aluminum. Prior to World War I, magnesium was imported from Germany at \$1.65 per lb., a value on the same order of magnitude as titanium's present cost of \$5.00 per lb., when depreciation of the money is considered. Dow Chemical Co. was able to break even on its costs in 1926, when it produced 100 tons of magnesium and sold it at 69¢

\*EDITOR'S FOOTNOTE - A Yankee guess might

be made as to the cost of titanium metal when

(approximately \$1.50 in present money). 1950 cost of magnesium ingot was 24.5¢ per lb., when made at the rate of 24,000 tons per year—an example of how mass production brings down the price of an article.

Since 1 lb. of magnesium and 1 lb. of aluminum require nearly the same energy to reduce them from their ores—chloride and oxide, respectively—it may be guessed that the eventual price

of magnesium will equal that of aluminum, which is now 19¢ per lb, with U. S. production of about 650,000 tons per year.

Titanium is not an easily reduced metal; although the heat of formation of the chloride is somewhat less than that of magnesium chloride. Likewise it has a very high melting point. When it is considered that (in the Kroll process) it takes 1.1 lb. of Mg to produce 1.0 lb. of Ti, it can be concluded that the price of the two will eventually be on the same order. One can therefore guess that in 1953 (when, for example, Titanium Metals Corp. of America plans on making 3600 tons in the wartime Basic Magnesium plant in Nevada) titanium ingot will cost on the order of \$2.00 per lb., — that is to say, somewhat more than Dow's 1926 cost of magnesium, in 1950 dollars.

P. S. — All the above thinking is about *ingot*. The usual large multiplying factors must be used to compute the selling price of fabricated articles.

which must be channeled into design handbooks and drafting room manuals.

It is recognized that present methods of melting and casting are not entirely satisfactory. A great deal more will have to be learned concerning processing and fabrication before finished products of this new material can be made with a uniformly high quality in the amounts necessary to meet the potential demand.

Nevertheless, the fact remains that titanium and a number of its alloys possess unusually attractive properties as structural materials. They are inherently stable, that is, resist corrosive attack in environments where structural materials are normally used. Titanium has a higher melting point than iron, and eventually alloys should be developed with good mechanical properties and oxidation resistance in the range of 800 to 1200° F. and possibly up to 1800°. At room temperature and up to 800°, alloys are now available with excellent mechanical properties.

# Improving Bendix Airplane Landing Wheels by Burnishing

An article in the August issue of Metal Progress by George H. Found of Dow Chemical Co. (p. 51) discussed methods of increasing the endurance of magnesium castings by surface work. It will now be my purpose to bridge the gap between the laboratory tests he reported and the shop use of surface treatment. This discussion, therefore, will describe tests on full-scale models of relatively complicated aircraft wheels cast in magnesium alloys. Comparisons will be made of certain surface treatments - namely. ball peening, and burnishing or rubbing - and some remarks will be made about the difficulties and techniques involved. We will also outline some of the conclusions determined by the Bendix Products Division and the feasibility of using these treatments on production parts.

It should be pointed out at the beginning that our work may be considered inconclusive from the standpoint of number of tests made. While it may be practical to run a large number of identical test bars at the same load condition, this is not true on full-scale aircraft

wheels. In the first place, these tests are slow and expensive. We use the specially designed machine shown in Fig. 1; it cost approximately \$50,000 and requires two men to operate it. About the best we can do on an aircraft wheel of average size is to roll 100 miles in a 24-hr. day. Aircraft tires, as now designed, are not made for continuous high-speed service and therefore have very short life under the test conditions; failure may be expected at from 50 to 300 miles. There is considerable doubt about the real effect of sudden release in load in this machine which

occurs when a tire blows out. This may have considerable effect on the ultimate service life of the wheel. In the second place there is the difficulty in duplicating test pieces. Although machining dimensions may be held quite accurately, variations in the wall sections at critical areas in a sand-cast wheel may reach a considerable percentage. This will affect the ultimate life of the part materially. Unquestionably, the totality of casting variations—soundness, porosity, nicks on the surface, over-all finish smoothness—have a large effect on service life. All this should be pointed out, since each of these items will have a bearing on the conclusions drawn from tests.

Early in 1946, the Bendix Products Division

was ready to accept the statement that surface treatment had much to do with ultimate service life. We felt this was particularly true in aircraft wheel design, as we possessed some rather perplexing information on wheel failures wherein fractures had

occurred at sections where strain gages showed relatively low stresses (4000 to 5000 psi.) and others where failures did not occur in sections

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stressed as high as 10,000 to 11,000 psi. We were led to the belief that actual failures started from some defect in the outer fiber or at the surface. For example, improper cleaning of sand from the ribs of a wheel casting is a very important contribution to failure. Blowholes, excess porosity of the surface, core matching lines, and many other common defects of this nature would seriously affect the ultimate fatigue life. We had also concluded it was not always sufficient to add metal at the point of failure, provided the surface defect remained. In other cases, it was impossible to decrease the working stress at particular points of failure, such as at the radius between the bead seat and vertical flange section, because such radii are dictated by tire designs.

Burnishing—One of the required tests is that aircraft wheels must endure a roll test of 1000 miles minimum at their rated capacity without failure. When our 17.00-20 wheel was increased in capacity from 20,500 to 25,000 lb., fatigue failures occurred in the demountable flange in the radius between the bead seat and vertical flange section (Fig. 2). Inasmuch as there are many of the wheels rated at 20,500 lb. in service, interchangeability of flanges between the designs was desirable, thus making it impossible to increase the section at the point of failure, and it was necessary, therefore, for the part to carry a larger stress in this region.

Table I shows tests which demonstrate the effect of burnishing at the critical section. The

first test was on a standard wheel with a machined but unburnished flange; it will be noted failure occurred at 300 miles. The second test was essentially the same wheel design but particular care was taken to get a smooth section at the point of expected failure and also to get the best fit between flange and cylindrical barrel of the wheel. Here failure occurred at 813 miles.

The third test was on the same wheel and flange design with the exception that an annular groove was cut on the inside diameter of the demountable flange so as to relieve the stresses at the critical section in the radius. Here failure occurred at 1005 miles by a crack in the relief groove. This cannot be considered as comparable for the reason that it incorporated a design change. It would better be said the life of the machined flange of standard design without burnishing was somewhere between 300 and 813 miles under the test conditions. Further tests and experience on this flange would indicate the higher value (800 miles, approximately) is more indicative of true service life.

The fourth test shown in Table I was the first attempt at using a burnished flange. The surface of this flange (of which four sections were cut after the test) was burnished between points A – A in Fig. 2. At 1000 miles there were no cracks evident. The first indication occurred at 1100 miles, with a very small crack in the critical section. The test was carried on to 1250 miles before the crack had extended to the dangerous point. Minute inspection then indicated

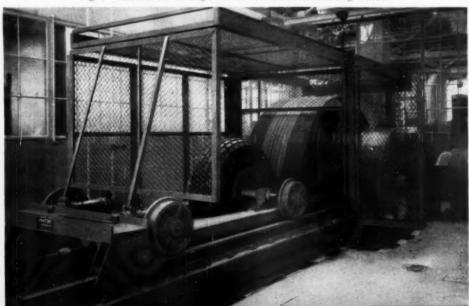


Fig. 1 - Machine for Testing Performance of Aircraft Landing Wheels

Table I - Life of Machined and Burnished Flanges on 17.00-20 Wheel Loaded to 25,000 Lb.

| TEST   | TIRE PRESSURE | FINISH    | MILES | Condition                                                            |
|--------|---------------|-----------|-------|----------------------------------------------------------------------|
| No. 1  | Unknown       | Machined  | 300   | Small cracks at bead seat radius                                     |
| No. 2  | 108 psi.      | Machined  | 813   | Small cracks at bead seat radius                                     |
| No. 3* | 105 psi.      | Machined  | 1005  | Crack in relief groove                                               |
| No. 4  |               | Burnished | 1000  | No cracks                                                            |
|        |               |           | 1100  | Small cracks in area of light burnish                                |
|        |               |           | 1250  | Area of failure slightly increased                                   |
| No. 5  | 103 psi.      | Burnished | 1700  | Fine cracks at bead seat radius                                      |
| No. 6† | 100 psi.      | Burnished | 1700  | Fine cracks at bead seat radius through area containing microporosit |

\*Design change — groove machined on inner surface of flange to relieve stresses on bead seat radius. 
†Salvage test on flange rejectable because of undue microporosity shown by radiograph.

that a perfect job of burnishing had not been done, primarily due to the method of mounting and a slightly out-of-round condition of the flange. In other words, rubbing had not been consistent throughout the complete periphery. As might be expected, the failure occurred at the spot where the burnishing treatment was the least effective or had the least penetration.

The next test used a burnished flange but care was exercised to improve the burnishing technique to obtain uniform surface working. The results were quite satisfactory; the flange went 1700 miles before showing any failure.

The final test was in the interest of salvage, to check the effect of rather heavy porosity (Fig. 2) considerably more than we would allow through our production standard. This flange was burnished the same as in the previous test. Here again the results were very gratifying, as we got the same amount of roll as in the previous test on a standard flange with a minimum of porosity. A microscopic examination of this flange after the test revealed heavy porosity, but it did not extend to the surface adjacent to the starting point of failure; consequently it should not have influenced fatigue properties adversely.

The complete program on the 17.00-20 wheel required some eight months to complete and included many runs other than those listed in Table I. These additional tests incorporated design changes as well as changes in surface treatment, and the conclusions drawn from them are not entirely conclusive, as it is hard to evaluate which change was responsible for an increase or decrease in the fatigue life. It can be stated, however, that burnishing always seems to have a positive effect toward increasing service life. Table I itself would indicate an increase in ultimate life of the flange from 800 to 1700 miles — approximately double.

Another critical section is in the retainer ring groove of the wheel proper, a semicircular groove matching the region marked C in Fig. 2. We tested a 34 x 9.9 wheel assembly similar in design to the 17.00-20 size already discussed. The first test cracked in the machined retainer ring groove at 810 miles. The second test on a (commercially) identical wheel showed 570 miles; a crack developed in the internal ribs. The third test (also with as-machined groove) cracked in the groove at 925 miles. In the fourth test, when the retaining ring groove was burnished and the assembly tested under the same loading conditions, the wheel went 1250 miles without trouble in the burnished groove, but the wheel cracked in an internal rib.

It would seem from these data that the expected life in the retainer ring groove section on the as-machined wheel was approximately 925 miles. With the burnished section, we can only conclude that the fatigue life is more than

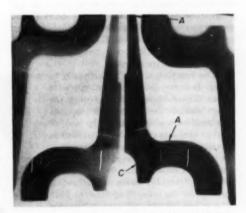


Fig. 2 — Radiographs of Four Sections Cut From Test 6 (Table I) Showing Cross Section of Flange, Extent of Burnished Surface, and Location of Fatigue Cracks Near Bead Seat Radius. Surface A-A is burnished; surface C mates semicircular groove in wheel rim to house a retainer ring

1250 miles, as no failure occurred up to this point. Again we must conclude that the burnishing operation materially increased the service life of the wheel, although it isn't conclusive how much this life was increased.

#### SHOT PEENING

Our experience with shot peening had not been as extensive or as conclusive, since it is confined to four tests on the 17.00-20 wheel, sand cast in magnesium alloy. Testing conditions were uniform, the average tire pressure being 115 psi, and the wheel loading being 31,500 lb.

Test A was stopped at 727 miles when cracks were discovered through the valve stem hole, extending 10 in. around the perimeter and into the inner ribs. This casting had no surface treatment.

Test B was also on an as-cast wheel. At 787 miles small cracks were found in the valve stem hole, and at 920 miles one crack had progressed 2 in. and extended into an inner rib. A crack was also found in the retainer ring groove.

Test C was the same except that the inboard spokes were smoothed by hand with emery paper and the window radii made more definite. This run was stopped at 731 miles, when small cracks were found on two inboard spokes.

These first three tests are essentially the same wheel design, tested under the same conditions. Life varied from 727 to 920 miles; two types of failure were indicated, one of a localized nature around the valve stem hole, and one of a more serious nature in the cracking of spokes and internal ribs. The latter may have been the result of inferior metal on

the surface, or of internal stresses not relieved by heat treating.

The fourth test was unfortunate, in a way, because two modifications were made. The first was shot peening the spokes and all the internal rib sections with moderate sized shot. The second was a stabilization heat treatment intended to relieve any residual stresses. The combination of the two changes materially increased the fatigue life of the wheel. At 1351 miles a small crack appeared in the inboard spoke. At 1401 miles a 2-in. crack appeared in the rim at the valve slot which was the localized point of failure. Finally, at 1735 miles, the wheel cracked entirely through one spoke. It must be concluded, therefore, the combination of stabilization and shot peening more than doubled the life.

We did not go into production with shot peening because of the difficulties involved in effectively working the inside of the wheel with available equipment. It was almost impossible to direct shot through the small openings or windows in the side of the wheels and strike perpendicularly the ribbing at the critical section. The wheel might be mounted on an inclined spindle and the shot directed at an angle so that the internal ribs would be effectively peened. but the expense of such a setup and the possibility that it would still give inconsistent peening on the various sections of the wheel decided us against this procedure. Instead, the design was changed so as to increase the section of the spoke at the point of failure. When such a wheel was tested, after stabilization by heat treatment, it had approximately the same life as in the fourth test just described, so it was adopted as our standard production wheel.

We can only conclude from these results that shot peening is effective if carefully controlled and if the blow is perpendicular to the surface being treated. It does not work out too well for the inside of wheel castings, because of inaccessibility—yet this would be the ideal spot for such treatment, as it is impossible to machine or smooth these areas. Such surfaces should be peened only where they are essentially regular, with no high ribs adjacent to long sections of essentially flat nature.

Our experience has been mostly with fairly large shot — 0.032 to 0.055 in. It is very desirable to screen the shot at frequent intervals to remove any broken or fragmented shot.

Fig. 3 — Burnishing Tool Merely Replaces Cutting Tool and Automatically Generates the Same Surface on the Outside of the Flange



#### PRODUCTION BURNISHING

Our laboratory experience of burnished wheels and flanges warrants its use on all magnesium wheels in production except the smaller sizes where minimum sections dictate a conservative low-stressed design.

Wheels are machined in lathes equipped with profile templates for a single finishing cut over the entire rim. We intended to use the same equipment, in the same setup, substituting a burnishing tool for the normal cutting tool. (See Fig. 3.) This required a tool with circular end and a spherical burnishing tool so the same surface would be generated with both. The radius is the most critical section of the entire rim profile and should be a generated burnishing operation instead of a series of concentric burnished rings. While tools must be sharper in curvature than the radius on the part itself, they should be kept as close as possible to the actual machined radius.

A series of tests was set up on production machines with speeds ranging from 57 to 1050 ft. per min., and feeds from 0.016 to 0.005 in. per revolution. Maximum penetration of burnishing tool was attempted, but if 0.003 in. it galled the metal. Most satisfactory penetration was 0.002 to 0.003 in. The highest speeds and the lowest feeds gave the best appearing surface. A spring-loaded burnishing tool (Fig. 4) will compensate for any out-of-round condition. A spring with a relatively low rate of response will follow surface variations with little change in actual load.

A study was also made of lubricants. We found that petrolatum, brushed on the surface, worked much better under the burnishing tool

Fig. 4 — Spring-Mounted Burnishing Tools; Roller (Left) and Ball (Right)

than a machining oil or other liquid lubricants.

The question may well be asked as to how we determine when a surface is properly burnished. A fair job can be done by visual inspection, because it will be smooth, with no indication of tear, and glazed slightly. This is particularly evident under low magnification. The correctly burnished surface has the appearance of a series of furrows turned over, with no fragmentation or loose chips in evidence. However, it is necessary to section a piece occasionally, polish and etch it, and then examine it microscopically. This shows very clearly the depth of penetration by strain markings in the grains near the surface. (See the photomicrographs in Mr. Found's article last month.) Such metallographical studies are highly recommended when evolving a technique to burnish a surface on a newly designed part. It is also important to start with a comparatively smooth machined surface; our specification calls for a 100-microinch finish. Yet we know of no inspection quite as good as that of the good operator. It might be said that a good-appearing surface is generally a good burnished surface.

#### CONCLUSION

Wheel designs are at best a compromise. One set of requirements dictates a strong rigid structure capable of withstanding five to ten times the normal rated load of the wheel. Since weight must be saved, this rigidity can be provided most efficiently through high ribbing and spokes. Yet a second set of requirements specifies long service life (resistance to fatigue). Warranties are being requested for service life of 10,000 miles rolling distance for landing, taxiing, and take-off operations. Here we should have a different structure, one of uniform sections throughout the circumference, a structure that yields uniformly without points of high stress concentration. Again, the wheel is a running mate of the tire, and the entire rim profile must be compatible with good tire design.

The result is that aircraft wheels are rarely ideal structures from the standpoint of longevity, due to the compromises in the design and resulting points of high stress concentration. Moreover, cast magnesium alloys are unquestionably somewhat notch sensitive, and should any smooth surface be interrupted at a point of high stress the result will be short life. Any surface treatment such as burnishing or ball peening that compensates for notch sensitivity and other factors contributing to scatter of test data, unpredictability, and short fatigue life should be a must in the design.

## Production of Powdered Uranium and Thorium

THE following is a description of the method of making powdered uranium and thorium which is used at the Ames Laboratory. This laboratory has prepared several batches of these powdered metals in response to requests from other units of the Atomic Energy Commission. The conversion to the powder form, done with ordinary laboratory equipment and in a short time, is simple. As an amount sufficient for some purposes can be made up in less than half a day, the powdered metals may be considered as always immediately available if one has the requisite massive metals on hand.

To prepare either powder, one needs only to allow the starting metal to react with hydrogen to produce the hydride, which forms as a powder, and then to decompose the hydride under conditions such that no sintering occurs. The production of powdered

uranium is particularly simple and will be described first. For reasons that will become apparent, thorium presents a slightly more complicated problem.

#### PRODUCTION OF POWDERED URANIUM

The natural division of the process into two stages may be followed conveniently in an explanation of the operations. The reaction between uranium and hydrogen produces uranium hydride, UH<sub>3</sub>. This compound forms as a powder so fine that it will pass a 400-mesh screen and has so little adhesion to the metal that it falls away continuously leaving a freshly exposed surface. Three principal factors controlling the rate of reaction between uranium and hydrogen are (a) area of surface of metal,

(b) temperature of the reacting substances, (c) pressure of hydrogen over the charge.

When the second and third factors are constant, the rate of reaction is proportional to the exposed area. For this reason, lathe turnings, pieces of thin sheet, or other subdivided forms of metal are converted more rapidly than the same weight of uranium in a single block. Thin flat pieces have the advantage also that the area available for reaction decreases only slightly during the progress of metal conversion.

The effect of temperature is less simple. The action of hydrogen on massive uranium becomes noticeable when the temperature of the metal reaches about 100 to 150° C. and proceeds most rapidly in the vicinity of 225° C., as indicated in Fig. 1. However, the purity of the hydrogen and the state of the metal affect the time necessary for conversion at any temperature. A small percentage of oxygen in the hydrogen delays the start of reaction, particularly at temperatures below 200° C. A slight oxide on the metal also causes a delay so that a

temperature above 225° C. may give the highest average rate. On the other hand, finely divided uranium, made by the decomposition of a previously made hydride and presumably completely free of oxide film, combines with hydrogen slowly at

-80° C. and briskly at room temperature. Figure 1 was obtained with purified hydrogen acting on uranium wire.

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Pressure of hydrogen also affects the rate of reaction. Higher pressures produce higher rates, but as the reaction is strongly exothermic, the higher rates may cause the temperature to rise above the allowable limit for the apparatus. A less serious consequence of the rise of temperature is a reduction of the rate of reaction in accordance with Fig. 1. Provided that the apparatus does not fail, an equilibrium will eventually establish itself between the increase in temperature and the decrease in rate of reaction. Adjustment of the flow of hydrogen to the reaction vessel is an effective means of controlling the rate of reaction and the consequent rise of temperature.

If the hydrogen pressure falls too low, conversion may be undesirably slow; an excessively low pressure will reverse the direction of the reaction. The pressure at which the reaction

<sup>\*</sup>Contribution No. 142 from the Institute for Atomic Research and the Department of Chemistry. The work was performed in the Ames Laboratory of the Atomic Energy Commission.

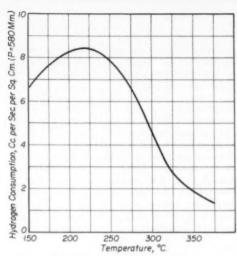
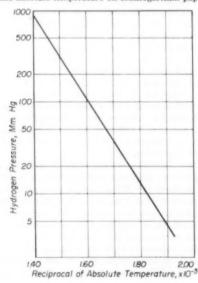


Fig. 1 — The Change in Rate of Reaction of Hydrogen With Uranium as Temperature Increases. Rates are for purified hydrogen reacting with uranium wire

does not proceed in either direction is shown as a function of temperature in the conventional way in Fig. 2. In Fig. 3, a section of this graph has been replotted with degrees centigrade as the principal variable. Obviously, if the pressure-temperature point representing any condition of the reacting system lies above the curve,

Fig. 2—Change in the Pressure of Hydrogen Over Uranium Hydride as the Temperature Is Varied. This graph shows the conventional plot of dissociation pressure against the reciprocal of the absolute temperature on semilogarithm paper



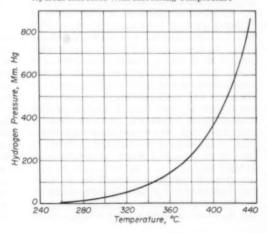
hydride will form, whereas, if the representative point lies below the curve, the hydride will decompose (metal will be formed).

The second stage of the process, the decomposition of uranium hydride to uranium powder, requires the removal of hydrogen under conditions suggested by Fig. 3. In general, decomposition will be more rapid as the pressure of hydrogen is reduced further below the equilibrium value. As indicated in Fig. 3, uranium hydride can be decomposed at atmospheric pressure if the temperature is raised above 430° C.\* although the resulting metal is less satisfactory for some purposes. During the decomposition stage, an increased amount of energy must be supplied to the furnace to compensate for the heat absorbed in the dissociation of uranium hydride. It is this absorption of heat that causes the sharp drop in temperature as dissociation begins when pumping is started.

Having set down some of the basic facts, we may now consider equipment and procedure. For the small amounts of powdered uranium occasionally prepared for laboratory use, perhaps 100 to 250 g., conventional laboratory apparatus such as that illustrated in Fig. 4 is satisfactory. An ordinary carbon combustion furnace is a suitable heating unit. A suitable container for the charge can be made by sealing one end of a Pyrex glass tube of the proper size to slide in the furnace. The other end of the tube may be provided with a ground, tapered joint to receive a cap that connects to the

\*Some data indicate that this value may be as much as 5° C. too high.

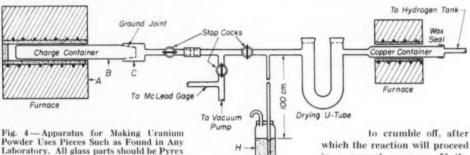
Fig. 3—Dissociation Pressure of Uranium Hydride Increases With Increasing Temperature



remaining apparatus. As a precaution against loosening of the cap if the pressure of hydrogen should rise above atmospheric value, the two portions of the joint may be tied together with string or wire. Connections to the vacuum pump and the hydrogen supply are made in the customary manner. As the hydrogen should be as free as possible from oxygen and moisture, it should be led through a tube containing copper at about 600° C. and a tower or tube containing a drying agent such as Mg(ClO<sub>4</sub>)<sub>2</sub>. An extremely effective purification of hydrogen is obtained if the gas is led over uranium turnings or powder at a temperature of 600 or 700° C.

Stopcocks should be provided for cutting off the connections to the pump and to the supflushed with hydrogen and power may be turned on the furnace. During heating, the pressure of hydrogen customarily is maintained slightly above one atmosphere.

Usually, the total time for conversion of small charges is decreased if the charge is maintained above  $225^{\circ}$  C., indicated in Fig. 1 as being the optimum temperature. The reason for a reduced total period of conversion at the higher temperature is the shortening of the incubation period described below. In most instances, enough oxide film remains on the uranium to prevent the entering hydrogen from making immediate contact with the metal. The gas must first diffuse through the oxide layer and form UH $_3$  in sufficient amount to cause the layer



ply of hydrogen. In particular, a stopcock immediately beyond the ground joint is desirable so that the container of powdered metal can be closed off from the air when it is disconnected from the remainder of the apparatus. With this arrangement, the container may be used to store the powder temporarily or may be attached to another piece of apparatus.

Because lathe turnings or other forms of uranium are likely to have an oxide scale which makes reaction proceed less rapidly, the charge should be cleaned in dilute\* nitric acid, washed with distilled water, rinsed in acetone, and dried. Time should be allowed for the acetone to evaporate completely before the turnings are disturbed, as a spark between pieces may cause the acetone to catch fire. A good precaution against trouble is to have a helium- or argon-fed cover ready to be set over any ignited substance. As soon as the turnings are dry they should be put in the container which should then be pumped out.

When the pressure of air in the container has diminished to 5 or  $10\mu$ , the system may be

\*The concentration of acid should not exceed 50% by volume if explosive action is to be avoided.

which the reaction will proceed in a normal manner. If the charge is in small pieces, the

time for diffusion at lower temperatures is a large fraction of the total time of conversion. For this reason, the charge usually is maintained in the range of 250 to 300° C. At this temperature a 100-g. charge can be converted to hydride in about a half hour. The reader should note that the temperature of the charge may be higher than the temperature of the furnace because of the exothermic heat of reaction.

In operation at any temperature, an estimate of the rate of conversion is obtained from observation of the rate at which hydrogen must be admitted to maintain an approximately constant pressure. When hydrogen is no longer taken up, the reaction has reached its practical end of conversion.

Decomposition of the hydride proceeds most rapidly if the hydrogen is pumped off as rapidly as it is given up. A high temperature is advantageous in this step because the higher existing dissociation pressure means that hydrogen comes off more rapidly. The temperature is limited, however, by the tendency of the reduced powder to sinter to particles of aggregate. This tendency becomes noticeable at 300 to 350° C. but still higher temperatures usually are

employed because mild jarring of the container suffices to break up the aggregates into individual grains even when the hydride has been decomposed at 400° C. or a little higher. An added advantage of the higher temperature is that the product is less pyrophoric than powder produced at a lower temperature. Under the conditions outlined, a 100-g, quantity of uranium hydride can be deprived of its hydrogen in about one hour.

The method of production outlined above has the merit that the strongly pyrophoric UH<sub>3</sub> is not exposed to the

atmosphere at any time. When necessary, uranium hydride at room temperature can be handled safely under nitrogen or carbon dioxide. Carbon dioxide is a convenient atmosphere since it can be obtained from a piece of dry ice and is quite safe if the temperature of the hydride is not above 100° C. At 200° C. an observable reaction between hydride and gas sets in and once the reaction becomes energetic it is difficult to stop. The reduced metal is less pyrophoric than the hydride but should be handled with precautions like those indicated for the hydride. Calcined lime smothers the ignited material sufficiently to prevent fire spreading to other objects, but the uranium usually reverts to the oxide once action has started.

#### PRODUCTION OF POWDERED THORIUM

Thorium reacts with hydrogen to form two hydrides — one with the formula  $ThH_2$  and another of undetermined proportions,  $ThH_X$ , but, apparently, either  $ThH_{3.75}$  or  $ThH_4$ . The hydrogen-thorium ratio seems to be sensitive to the conditions of formation. A consequence of the existence of two compounds is a pressure-composition curve with two levels as in Fig. 5, which shows the isothermal curve for 600° C. The left portion of this curve has been redrawn from Fig. 2 (in CC 2722) and corresponds to the reaction  $Th + H_2 = ThH_2$ . The right portion is an approximation based on calculations from the equation

$$P_{(mm)} = \frac{-4220}{T} + 9.50$$

corresponding to the reaction  $ThH_2 + (x/2 - 1)H_2 = ThH_x$ .

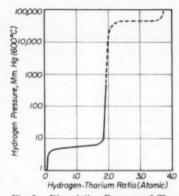


Fig. 5 — Dissociation Pressure of Thorium Hydrides at 600° C. Left portion of curve redrawn from Fig. 2 in report CC 2722; right portion is based on equation given in the same report

From an examination of this figure, one notes immediately that the dissociation pressure of the higher hydride is very much greater than that of the lower hydride at the same temperature. Evidently, the formation of ThH2 may proceed under lower pressures than are required for the preparation of ThHx at the same temperature, or, considerably higher temperatures may be employed in preparing ThH, than can be used in forming ThHx under an approximately fixed pressure.

These facts suggest the desirability of dividing both

the formation and decomposition steps of making powdered thorium into two parts. This procedure is as shown below:

- 1. Formation of dihydride, ThH  $_{\! 2},$  between 600 and 650° C.
- Formation of the higher hydride at temperatures not above 320° C.
- Decomposition of the higher hydride at temperatures up to 500° C, under a pressure of one atmosphere of hydrogen.
- 4. Decomposition of the lower hydride at  $700^{\circ}$  C. at low pressure.

Since the procedure is more complicated, more exact details are given for the production of thorium than were furnished for making uranium metal powder.

Seamless, plain carbon steel tubing is suitable for a container for thorium, although if the operator desires to take advantage of higher pressures and temperatures, a stainless steel tube would be preferable. For small lots, a fused silica tube may be used. A steel tube used in some production runs was 4% in. in diameter by 26 in. long and could hold 10 lb. of coarse thorium turnings with ample room for expansion of the charge during the formation of the hydride. One end of the tube was closed by a steel plate welded on; the other was cooled by a spiral of copper tubing through which water ran. Closure of the cooled end was by a water-cooled plate bearing a small pipe for connection to the remainder of the apparatus. The tube was provided with ears so that the cap could be fastened to it by means of clamps. The joint between tube and cap was made tight by means of a rubber gasket.

A large furnace similar to the small one

shown in Fig. 4, for making uranium powder, is a suitable source of heat. A thermocouple for measurement of temperature should be placed in contact with the steel container. Connections to suitable vacuum pumps and to the hydrogen supply must be provided in the manner described for uranium. For evacuation of the system, a diffusion pump backed by a mechanical pump, such as a Hypervac 23, is desirable. The pressure of hydrogen may be determined by an ordinary manometer, but a McLeod gage or other device for measuring low pressure also should be included in the system. Suitable means for purifying the hydrogen should be included, although experimental runs have been made with hydrogen as it came from the tank.

Turnings or chips are the most desirable form of charge as they react rapidly. However, blocks up to 4 in. in diameter (the cropped heads of 4-in. diameter ingots) have been used successfully. After the charge has been put in place and the cap fastened on the tube, the system should be sealed vacuum-tight. With the equipment described above, pumping for 20 min. should reduce the pressure to about 1µ.

After tests have shown the system to be free from leaks, power may be turned on the furnace and the temperature brought up between 350 and 400° C., which is about the minimum temperature at which hydrogen reacts with thorium. While the furnace is being brought up to temperature or at the beginning of the reaction period, hydrogen may be alternately admitted and pumped out as a means of sweeping out the products of degassing. Except during pumping, the pressure of hydrogen may be maintained slightly above one atmosphere.

If the charge consists of chips or turnings, the exothermic heat suffices to maintain the temperature in the converting range. If the temperature shows evidence of rising above 700° C., the hydrogen supply should be throttled down or diluted with helium or argon. Too much dependence should not be placed on the indication of the thermocouple at this time as the reaction may spread out from a single point while the remainder of the charge experiences little effect. Visual observation of the outside of the tube will show whether the charge is becoming excessively hot in one region. If the charge consists of large pieces, exothermic heat will not maintain the operating temperature and some energy must be supplied to the heating element.

The operator can determine the conversion rate roughly by watching the rate of decrease

of pressure when the supply of hydrogen is cut off temporarily. As the composition of the charge approaches the proportion  $\mathrm{ThH}_2$  the consumption of hydrogen becomes increasingly slow. This behavior indicates, in Fig. 5, that a point representing atmospheric pressure and composition of the charge, which has been moving steadily to the right, is approaching the vertical portion of the curve and is unable to cross it.

When the absorption of hydrogen at atmospheric pressure has ceased, the temperature of the furnace may be allowed to decrease until consumption of hydrogen again becomes energetic which it does about 320° C.\* Absorption of hydrogen continues at temperatures as low as 100° C. and below, but the action is most rapid about 250° C. When the consumption of hydrogen stops again, the operation is complete.

The lower hydride of thorium forms with little disintegration of the charge although a swelling, corresponding to the decreased density, is observed. During the formation of the higher hydride, grains of hydride begin to fall off and the pieces of the charge lose their individual outlines. Jarring of the container during or after the reaction period will cause the pieces to break up noticeably but much of the charge remains in relatively coarse particles about the size to pass a 30-mesh screen. For a 10-lb. charge of turnings, the time for conversion to the higher hydride under atmospheric pressure is a little more than 6 hr., of which about 2 are spent in the reaction of thorium to ThH2 and 4 are required for production of the higher hydride after the temperature of the furnace has diminished to the reacting value.

Decomposition of the higher hydride can be performed under atmospheric pressure easily if one increases the temperature of the furnace gradually to 500° C. When no more hydrogen comes off, the temperature of the furnace may be increased again to about 700° C. and decomposition of the dihydride started under pumping. Evacuation should be continued until the pressure of hydrogen is below 1 mm. of mercury. This condition corresponds to a very low percentage of hydride. The pumping period for a 10-lb. charge of chips is about 4 hr., and for the whole operation of hydrogen removal is about 6 hr. For a 22-lb. charge of large blocks, the pumping period lasts about 8 hr. under the conditions outlined.

<sup>\*</sup>Since the dissociation pressure of the higher hydride at 350°C. is only 500 mm., one would expect that the reaction would start above this temperature.

After reduction of the hydride is complete, the container should be cooled and flooded with argon or helium. When the cover is removed, a piece of dry ice may be dropped into the container to provide an atmosphere of CO2. The product as taken from the container is coarsely granular but contains some larger pieces. Most of the material will pass a 30-mesh screen and a little of it will pass a 100-mesh screen. If desirable, the entire product may be ground to pass a 100-mesh screen, but as the metal is pyrophoric, the possibility of ignition is present unless the work is done under CO2 or an inert atmosphere. The product can be handled in air at ordinary temperature without ignition. If stored, it should be kept in a closed container.

In addition to the practice of grinding the final product, two other methods are available for the preparation of fine powder. The particle size can be decreased by repeated cycles of formation and decomposition of the hydride. However, this method is time consuming. An alternative procedure is the grinding of the charge during the hydride stage. Steel balls are placed in the reaction tube along with the charge. Then, after the hydrides have been formed, the reaction tube may be detached temporarily from the remainder of the apparatus and used as a ball mill for grinding the charge under a hydrogen atmosphere. The hydride is

quite brittle and breaks up rapidly into a very fine powder. This finely divided hydride can then be decomposed as described above. If the decomposition is carried out at 700° C. or below, very little sintering takes place. The contamination of the thorium powder by iron picked up from the steel container is slight; it certainly is less than 50 parts per million. Thorium powder reduced from the ball-milled hydride contained 175 parts per million of iron.

### ACKNOWLEDGMENTS

Except for the details of the method for making powdered thorium, which are based on the experience of the senior author, most of this review is a summary of reports in the files of the Ames Laboratory of the Atomic Energy Commission. Figure 1 was taken from LA Report 37. Virtually all other data are from work done at the Ames Laboratory at various times since the beginning of 1943. The investigations were made under the direction of F. H. Spedding and H. A. Wilhelm by N. C. Baenziger, T. A. Butler, A. H. Daane, I. B. Johns, O. Johnson, A. S. Newton, R. W. Nottorf, J. E. Powell, R. E. Rundle, J. C. Warf, and A. S. Wilson.

The authors are also indebted to A. H. Daane and D. Ahmann for additional information for the making of uranium powder.

### Properties of Uranium, Thorium, and Their Hydrides

| PROPERTY                          | Unit                | URAN                        | IUM                      | 1711                               | T                        | $\mathrm{TnH}_2$            | ТиН <sub>х</sub>               |
|-----------------------------------|---------------------|-----------------------------|--------------------------|------------------------------------|--------------------------|-----------------------------|--------------------------------|
| PROPERTY                          |                     | α                           | Υ                        | UH <sub>3</sub>                    | THORIUM                  |                             |                                |
| True density<br>Density as powder | g./ec.              | 19.0                        | _                        | 10.9<br>3.4                        | 11.7<br>2.7              | 9.20                        | 8.33                           |
| Cell structure<br>Dimensions of   |                     | orthorhombic <sup>1</sup>   | b. c. cubic <sup>2</sup> | cubic <sup>3</sup>                 | f. c. cubic <sup>4</sup> | b. c. tetr. <sup>5</sup>    | cubic <sup>6</sup>             |
| unit cell                         | Ä                   | 2.852<br>5.865<br>4.945     | 3.467                    | 6.63                               | 5.08                     | 4.09<br>5.02                | 9.09                           |
| Metal atoms<br>per unit cell      |                     | 4                           | 2                        | 8                                  | 4                        | 2                           | 16                             |
| Space group<br>Heat of formation  |                     | $\mathrm{D_{2h}^{17}-Cmcm}$ | $O_b^{\ p} = Im \ 3m$    | $O_h^3$ , $O^2o^nT_d^4$<br>-30,500 | $O_h^5 - Fm 3m$          | $D_{4h}^{17} = ?$ $-35,000$ | $T_d^6 - I\bar{4}3d$ $-19,000$ |
| Dissociation equation             | P <sub>(mm)</sub> = |                             |                          | $\frac{-4500}{T} + 9.23$           |                          | $\frac{-7700}{T} + 9.54$    | $\frac{-4220}{T} + 9.50$       |

 "The Crystalline Structure of Uranium", by C. W. Jacob and B. E. Warren, *Journal*, American Chemical Society, Vol. 59, 1937, p. 2588 to 2591.

 A. S. Wilson and R. E. Rundle, Atomic Energy Commission AEC D-2046 (to be published in National Nuclear Energy Series).

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4. "Eine neue Anordnung für röntgenkris-

tallographische Untersuchungen von Kristallpulver", by Helge Bohlin, *Annalen der Physik*, Ser. 4, Vol. 61, 1920, p. 421 to 439.

 R. E. Rundle, A. S. Wilson, R. W. Nottorf and R. Ræuchle, Atomic Energy Commission AEC D-2120 (to be published in Acta Crystallographica).

 "A Physical Study of the Thorium-Hydrogen System", by R. W. Nottorf, A. S. Wilson, R. E. Rundle, A. S. Newton and J. E. Powell, CC 2722, March 8, 1945.



As a measure to conserve critical chromium, nickel and molybdenum, boron steels have been recommended for those applications in which the conventional triple-alloy steels are selected primarily according to their hardenability properties. The H-band data for certain boron steels made in considerable tonnage match very satisfactorily the H-bands of higher-alloy conventional alloy steels they have replaced. Also, there is available a considerable amount of information that recommends the use of these steels on the basis of properties determined by laboratory investigation; however, there is very little published information that concerns their behavior under production and service conditions. The nine years of experience accumulated by Caterpillar Tractor Co., Peoria, Ill., in the processing and service studies of some of these steels provides a commentary that will be of interest to potential users of the new series and that means practically everybody because the supply situation is becoming tighter.

Caterpillar's experience with boron steels dates back to the early days of World War II when boron was first considered as a possible substitute for some of the chromium, nickel and molybdenum content of the "high-potency" alloy steels. Subsequent developments led to the adoption of the NE Steels (National Emergency Steels) which made such good use of the "tramp"

alloy in remelting scrap that concentrated interest by Government and industry in the more economical boron steels came to an end. However, on the basis of the results that Caterpillar, and others, had obtained from these early investigations, Caterpillar continued working with trial heats of boron-treated steels until sufficient evidence was obtained to order mill heats in substantial tonnages. The steels they concentrated on and have been using since that time are 86B45\* as a replacement for 2345 and 4340, and 14B35 (formerly designated as 10B35) for 3140 and 4140. Not a single failure of a part, despite many years of rigorous service, has been attributed to the use of boron-treated steels.

According to F. F. Vaughn (who has assisted chief metallurgist Glen C. Riegel in the Caterpillar boron steel program) a factor that has assured successful use of these steels is that material is selected on the basis of meeting specifications for minimum hardenability and notch toughness. By taking tests from locations which represent extremes within the mill heat—that is, the bottom of the first ingot and the top of the last ingot that are to be used for a given specification—the danger of putting into production material that is unsuitable for the part is eliminated to a very great extent. The tests

<sup>\*</sup>See Data Sheet, p. 80-B, in last month's Metal Progress.

Engraving at Head of the Article Represents Caterpillar's Famous Equipment for Progressive Heat Treatment of Bar Stock for High-Strength Bolts, Capscrews, Studs and Similar Screw Machine Parts. The four lines of induction equipment handle boron steel 14B35 in stride

performed are for Jominy end-quench hardenability, impact and tensile strengths and hardness. In addition, spectrographic analysis is made for boron.

Parts made of 86B45 are axle shafts, wheel spindles and steering knuckle arms. The 14B35 grade is used for bolts, capscrews and studs under 1/2 in. and over 3/8 in. in diameter; intermediate sizes are of fine-grained 1038 which is selected on a hardenability basis to meet the optimum requirements of the specification for these parts. Sizes under 1/2 in. are oil quenched; the water quench is used only for diameters over 3/8 in. All of these parts require thorough hardening to withstand the high stresses imposed on them during service. Final structure of the metal for all parts is tempered martensite. Sizes, which range from under 1/2 in. for the bolts to 5 in. for axles, together with the specifications, give a good indication of what can be expected of boron steels.

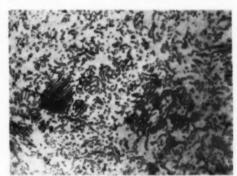
Typical specifications for these items run as follows: The 1¼ to 5-in. steering knuckle arms, wheel spindles and axles of 86B45 call for a minimum Jominy hardenability of Rockwell C-50 at a distance of 10/16 in.; the 14B35 bolts require a minimum hardenability of Rockwell C-40 at 4/16 in., 145,000 psi. tensile strength, an Izod impact strength of 36 ft-lb. at -20° F. and 42 ft-lb. at 75° F., using a 0.010-in. radius "V" notch; 7% to 13%-in. studs of the 14B35 grade steel require an 80,000-psi. minimum yield strength, a notch toughness (Izod impact, "V" notch) of 40 ft-lb. at -20° F. and 50 ft-lb. at 75° F., and hardness of C-20 to 28.

Caterpillar has used approximately 20,000 to 25,000 tons of 86B45 and 30,000 to 35,000 tons of 14B35 during the past nine years. The total steel tonnage used annually by this sprawling plant of 128 acres of modern buildings employing 22,000 production workers approximates a half million tons. It may be of interest to note that Caterpillar's several suppliers of the boron steels have been using Grainal 79 as the boron addition agent.

Mr. Vaughn states they have had no difficulty in machining, forging or heat treating the boron steels. In fact, the advantages offered in machining and heat treating that were discovered as soon as the steels were thoroughly investigated were deemed sufficiently important by the company to put up with the early tribulations in getting mills to accept these "special" analysis steels. However, some effort must be made to obtain a structure that is best suited for a given machining method. For example, if turning involves the greatest part of the machining time and hobbing or broaching are secondary, then the structure should be relatively soft so that turning can be done in minimum time, although some compromise must be made to have sufficient hardness to prevent serious tearing of metal during hobbing or broaching.

In the annealed and as-rolled condition, boron-treated steel is softer than conventional alloy steels of comparable hardenability, thereby giving tools and dies a longer life. This increased tool life has been reported by firms making bolts for Caterpillar and some of this information was quoted by Porter R. Wray in the article "Boron Steels for Constructional Parts and for Carburizing" which appeared in Metal Progress for July 1951. In that article the production of 8640 and 1035+B cold headed bolts and capscrews is compared to show the number of pieces that were run before it was necessary to regrind tools and dies, the 1035+B steel giving as much as a 2 to 1 gain over the 8640. Machining time for 86B45 axles has been reduced 25 to 30%, annealing time being shortened also.

The remarks made by Mr. Riegel on April 9 of this year at the Chicago meeting of the Oil



Annealed Structure of 86B45 for Best Machinability, Obtained in a Special Continuous Annealing Furnace. Picral etch, 1500 ×

ANNEALING CYCLE

Heat to 1600° F.
 Cool to less than 800° F. (accelerated controlled atmosphere)

ntrolled atmosphere)
3. Heat to 1380° F.

4. Cool to 1210° F. (accelerated controlled atmosphere)

5. Hold at 1210° F. for 3 hr. 6. Cool to less than 600° F.

7. Discharge

Field Supply group briefly summarize some of the important practices observed by his company:

"Normalized or air cooled sections of shafts, such as the bevel pinion and shaft or the spur pinion and shaft, on which only the gear end is liquid quenched, might give trouble by being low in hardness - and hence in strength - on the air cooled section. This could result in twisting off in torsion. Therefore, to obtain any value from the boron alloving agent. the part must be liquid quenched and tempered.

"Intensifying the hardenability of low-carbon steel, such as that in the core of carburized gears or similar parts of thin section, might result in a serious hazard from overall brittleness. Thus, in a thin-tooth section, the stress conditions may reverse in hardening, due to the formation of martens-

ite in the core subsequent to the hardening of the case and cause the tooth to be easily broken off by shock. Instead of having the case in compression and the core in tension, the tooth then is as brittle as if it were made of 'throughhardened' steel.

"Some sacrifice of hardness of carburized cases quenched from the carburizing temperature of 1700° F. or higher has been observed in the boron-treated steels. Quenching from temperatures only slightly above the upper transformation range or by reheating for hardening has been found satisfactory.

"Generally speaking, our experience has shown that in using boron-treated steels, we have had to reduce the carbon content of the steel it replaced by as much as three to five points. There is one disadvantage in using the lean alloy boron steels to replace the common constructional grades of alloy steel, namely the higher temperatures necessary for retaining ferrite in solution during quenching. This produces more distortion and unless more energetic means are used for removing the heat properly, there



Boron Steel 86B45 Has Been Used for Several Years by Caterpillar Tractor Co. for Highly Stressed Axle Shafts, Spindles, and Similar Heavy Section Parts of 3 to 6-In. Diameter

may result a poor product and high scrap loss."

Two continuous cycle annealing furnaces are used for the axles and the other parts made of 86B45. The first heating zone brings the metal to normalizing temperature from which it is cooled by a recirculating atmosphere; the second heating zone brings the metal to the austenizing temperature from which it is cooled as rapidily as possible, without undercooling, to the isothermal decomposition temperature. Electric induction heaters are used for progressive hardening and tempering stud stock in bar lengths.

Carburized 94B20 series has been used experimentally for transmission gears and final drive pinions with very satisfactory results. Inspections were made at 3000-hr. intervals up to 10,000 hr. and in some cases even to as much as 20,000 hr. of service under the various conditions that Caterpillar tractors, bulldozers and scrapers meet in practically all parts of the world. On the strength of this early experience, a contemplated change to the future use of this boron steel is not expected to present any problems in processing, carburizing, or service performance.

# Radioactive Tracers Reveal Friction and Wear of Metals

Алтноиси frictional phenomena have always been a part of everyday life, the basic knowledge of the mechanism underlying friction is very incomplete. Prior to 1920, friction was thought to be due solely to the mechanical interlocking of small irregularities or roughnesses on the rubbing surfaces. The force of friction was considered to be the tangential force necessary to slide the protuberances of one surface up the slopes of those on the other surface against the action of the normal force or load pressing the two surfaces together. On this basis the coefficient of friction, or ratio of tangential force to normal force, can be shown to be equal to the tangent of the mean angle of inclination of the surface irregularities.

While this hypothesis served to explain the so-called "laws of friction" observed by Amontons and Coulomb, it failed to account for the energy expended in the friction process. It can be seen that unless some other mechanism is responsible for friction,

sliding should proceed without the expenditure of energy, for the work to slide or lift one surface up the slope to the top of the protuberances of the other should be recovered upon sliding down the reverse slope. Then, too, careful measurements showed that improving the smoothness of the surfaces did not reduce greatly the friction coefficient as would be the case if this theory were correct.

The modern theory of friction, due to Hardy, Tomlinson, Bowden, Holm and others, postulates that the major part of frictional resistance is caused by molecular adhesion in those regions where the surfaces are in intimate contact and the resulting deformation of these regions on sliding. The finest of surfaces, be they ground, lapped, or polished, are rough by molecular standards and when two surfaces are pressed into contact, the applied load is carried entirely by a few high points which flow plastically until

they are large enough to support the load. The sum of these local areas is very small and constitutes only a small fraction of the nominal area over which the surfaces appear to be in contact. It is argued that, because of the high plastic flow pressures and intimate contact of the two surfaces at these points, a form of pressure weld or adhesion occurs over these local areas, even at room temperature. The force of friction is the summation of the

forces required to shear all of these minute welds and so permit sliding.

If the welds are weak because of contamination of the surfaces by oxide layers or greasy substances, or because the metals of the two surfaces exhibit little affinity for each other, they will usually break on the surface of original adhesion and little surface damage will occur. If, on the other hand, the metals are clean and mutually soluble in the solid state, the welds that are formed may be expected to be strong, their strength being further increased by local strain hardening from deformation and rubbing so that they are stronger than the materials of one or both surfaces.

Therefore, the welds should shear to one side in the bulk of the weaker metal and a minute particle of the softer metal should be found adhering to the harder metal. It should be kept in mind that this is not the gross welding

or visible galling observed on machine parts which have failed from inadequate lubrication but occurs instead on an extremely minute scale, far below the resolving power of the optical microscope. However, detection of the weld metal transferred from one surface to another during sliding is important in verifying and extending the adhesion theory of friction. Toward this end, a radioactive tracer method has been developed and used at the Massachusetts Institute of Technology Lubrication Laboratory.

## By J. T. Burwell\* and C. O. Strang† Massachusetts Institute of Technology Cambridge

### RADIOACTIVE TRACER TECHNIQUE

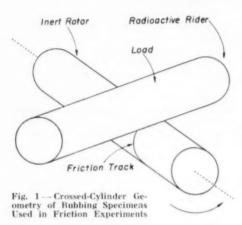
The radioactive tracer method for detecting metal transfer or "microwelding" is extremely simple in concept. It consists of making one of the two rubbing surfaces radioactive, rubbing

\*Now with Horizons, Inc., Cleveland.

†Now with Kiekhaefer Corp., Cedarburg, Wis.

them together under controlled conditions, and then examining the second surface for evidence of radioactivity. The first experiments (conducted in 1944 by Sakmann, Burwell and Irvine) demonstrated the feasibility of the method and showed that minute amounts of material from one surface were indeed transferred and adhered firmly to the second surface.

Experiments carried out before the recent war were difficult in practice because the active specimens had to be prepared either by irradiation in a cyclotron or by adding an active isotope to a melt of the specimen metal. The first method was poor from the quantitative standpoint as the resulting specific activity (disinte-



gration rate per unit volume of metal) of the metal, and hence its calibration, in terms of volume of transferred material, varied greatly with distance from the surface, the penetration of the bombarding beam being very low. The melt method was acceptable in this respect since it gave a uniform activity throughout the specimen but was very laborious in the preparation of finished specimens.

With the advent of neutron piles, however, material may readily be activated in a uniform manner by exposing the finished specimen to an atmosphere of slow neutrons, such as found in the uranium pile at the Clinton National Laboratory at Oak Ridge. The choice of isotopes is limited to those which can be produced by bombardment with slow neutrons. However, most metals commonly used for bearing or rubbing surfaces are suitable for this method of preparation although the sensitivity of their detection varies markedly. For instance, copper and chromium can be detected in extremely minute

amounts while iron is much less suitable for such experimentation.

Detection Methods - After carrying out the friction or wear experiment with the active and inert specimens, the latter is examined for evidence of transferred metal from the active specimen. This can be done in two ways. One is with the Geiger counter which gives a quantitative measure of the amount of active metal welded to the inert surface but yields little information as to its distribution. The other means of detection is by placing a sheet of X-ray film firmly in contact with the surface to be studied and allowing the radioactive particles adhering to the inert surface to take their own picture. This shows the distribution of transferred material and supplements the information obtained by counting methods. In the absence of a counter, comparative quantitative data may be obtained from the density of the photographs or autoradiographs as they are called, providing that care is taken in the control of exposure and development times.

Using both of these detection techniques, some examples are given in the subsequent discussion of the type of friction problems to which the tracer method can be applied and the light that it can throw on the nature of friction.

Effect of Lubricant — To study the effect of using a lubricant between sliding surfaces, a series of friction tests was conducted using a laboratory friction apparatus. This consisted of two cylindrical steel specimens pressed together with their axes at right angles to make contact at one point as shown in Fig. 1. The radioactive specimen was held stationary while the inert specimen rotated about its own axis so that the friction track consisted of a band around the rotating member.

Figure 2 is an autoradiograph of the tracks left by two such tests on a single rotating specimen in the absence of a lubricant. Since the film was wrapped around the cylindrical specimen to make the exposure, each track appears as a straight line when the film is unrolled. In this case the inert, rotating specimen was a superfinished casehardened steel and the radioactive cylinder was a hard-chromium plated steel. It will be noted that the transferred metal is not smeared or in a solid track but appears in discrete spots as though there had been individual welds. Very little surface change on this specimen was visible to the eye. This test was conducted with clean, dry surfaces.

Figure 3 shows the results from a similar experiment wherein two tracks were made using white mineral oil as a lubricant (tracks A and



Fig. 2 — Autoradiograph of Radioactive Chromium Transferred to Casehardened Steel Surface During the Dry Sliding Friction Tests

Fig. 3 (Right) — Autoradiograph of Chromium Transferred to Casehardened Steel When White Mineral Oil Is Used as a Lubricant (A and C) and When Oleic Acid Is Used (B and D)

G). It can be seen that the track is much less heavy and also that it is considerably less spotty. Two other tracks were made with oleic acid, but despite the presence of this very good boundary lubricant, some transfer or welding took place (tracks B and D).

The tracks made with oleic acid do not appear very clearly in the reproduction but are quite visible on the original negative. A quantitative measure of the transfer was obtained with the Geiger counter and is shown in Table I for the same test conditions.

Other investigators have shown by a similar type of experiment that the reduction in amount of material transferred with a good lubricant was due entirely to a reduction in the size of each weld while the number of welds remained the same. They further showed that transfer would also take place in the absence of sliding — merely by pressing the two surfaces together.

From these and many other experiments of a similar type, it has been found that this transfer of metal from one surface to another always takes place no matter how good the lubricant and is an intrinsic part of the friction process,

thus confirming the hypothesis that friction is due, in part at least, to the formation of minute welds. On the basis of results such as those in Table I, it would appear that the quantity of metal transfer occurring between two surfaces is a measure of the tendency of these metals toward large-scale galling and seizure, such as one observes on failure of a machine part. Hence, the tracer technique may provide a very rapid means for evaluating the galling resistance of materials for a given application, and thereby reveal their wear.\*



Effect of Surface Hardness - In order to study the effect of hardness on the microwelding, measurements of transfer were made with a series of nitralloy specimens of graduated hardness. The geometry of crossed cylindrical specimens was used for the friction tests and the quantity of metal transferred from active to inert specimen was measured with a Geiger counter. These tests were carried out with clean specimens in the absence

Table I — Amount of Transfer From Chromium to Hardened Steel Surfaces

| LUBRICANT USED    | COEFFICIENT<br>OF FRICTION | TRANSFER,<br>MICROGRAMS |  |
|-------------------|----------------------------|-------------------------|--|
| None              | 1.10                       | 1.5 to 3.5              |  |
| White Mineral Oil | 0.14                       | 0.10                    |  |
| Oleic Acid        | 0.11                       | 0.0001 to 0.01          |  |

of a lubricant. A single radioactive specimen was used as the stationary member and the hardness of the rotating or inert specimen was varied. Results of this set of tests are given in Fig. 4 and it will be seen that the quantity of transfer to the moving specimen increases continuously with the hardness of the moving specimen. It is interesting to note that the curve shows no discontinuity at the point where the hardness of the radioactive stationary member becomes less than that of the moving specimen, from which we must conclude that to some extent the transfer occurs in both directions simultaneously.

Similar results were obtained with radioactive specimens of hard chromium plate and moving specimens of nitralloy, although the quantities of transferred metal were smaller.

<sup>\*</sup>Bowden and Moore have shown, by following the radioactive metal, that certain oil additives will chemically react with and remove small amounts of metal from a surface exposed to them. Conversely Clark, Gallo and Lincoln have studied the film formation on solid surfaces made by other types of oil additives with the use of a radioactive atom in the oil. As these experiments were done in the absence of rubbing, they are purely chemical problems and are only mentioned here in passing.

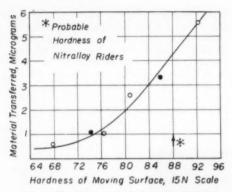


Fig. 4 — Metal Transferred From Nitralloy Riders to a Series of Moving Nitralloy Surfaces of Varying Hardness for a Given Distance and Load

This is not unexpected, for the chromium was somewhat harder, and it has also been observed that metal transfer is less when the two surfaces are dissimilar than when they are the same. All of the foregoing tests were run under the same conditions of load, sliding velocity, and sliding distance, while surface finish was carefully controlled.

The observed trend with hardness further substantiates the microwelding hypothesis of friction because with increasing hardness of the receiving member relative to the donating member of the friction pair, one would expect that the welds would be increasingly liable to break on the side of the latter, thus leaving greater amounts of material on the receiving surface. The fact that material is transferred even when the receiving surface is softer than the donating surface shows that the choice of which side of the weld will rupture on sliding is somewhat random in an individual case and only varies statistically with the relative hardness of the two.

Effect of Material Composition — While the foregoing data show that metal transfer increases

smoothly with relative hardness of the receiving specimen, this holds only when the materials are similar. When widely different metals are used as the receiving surface, it is found that the effect of composition overshadows the effect of hardness. The data of Table II were obtained with a stationary radioactive specimen of cast iron rubbing on a variety of moving specimens which are arranged in order of increasing hardness in this table. It will be seen that the quantity of transfer does not follow the hardness alone but

varies with the material of the moving specimen. These runs were made with white mineral oil as the lubricant and the magnitude of the amount transferred is therefore appreciably lower than was found in the study of the effect of surface hardness where no lubricant was used.

Taking the S.A.E. 1020 steel as a reference, the S.A.E. 1119 picked up less material even though it was harder. This was probably due to the presence of the sulphide stringers which would be expected to break up the occurrence of the welds and possibly serve also as a solid lubricant. The S.A.E. 4027 picked up more material than the 1020, as would be expected from its increased hardness. The cast iron (which had a somewhat different composition from the cast iron of the donating surface) picked up relatively less than its hardness would predict, presumably due to the graphite in it. This is borne out by the reduced friction.

The carburized steels showed the most unexpected results. These four steels were the same S.A.E. 1020, 1119, and 4027 steels which were used in the softened state plus a fourth steel. The pickup in all cases lay between 0.10 and 0.15 micrograms. In other words, carburizing these steels sharply reduced the pickupdespite the increase in hardness. This may be due to the high concentration of carbides in the surface which would not be expected to weld easily to the iron in the cast iron donating surface. Hence carburizing, in addition to reducing wear of the surface being carburized through increasing its hardness, also reduces the pickup of material from the softer surface against which it is rubbing and, therefore, reduces the incipient galling.

### METAL TRANSFER IN MACHINE ELEMENTS

In addition to the laboratory results described above, the radioactive technique also lends itself to the investigation of the mode of action of

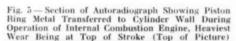
Table II — Metal Transfer From Lubricated Cast Iron to Various Receiving Surfaces

| MOVING SURFACE            | HARDNESS,<br>15-N Scale | COEFFICIENT<br>OF FRICTION | TRANSFER,<br>MICROGRAMS |
|---------------------------|-------------------------|----------------------------|-------------------------|
| S.A.E. 1020               | 46                      | 0.12                       | 0.50                    |
| S.A.E. 1119               | 57                      | 0.12                       | 0.21                    |
| S.A.E. 4027               | 60                      | 0.12                       | 0.88                    |
| Cast Iron<br>Average of 4 | 67                      | 0.10                       | 0.29                    |
| carburized steels         | 90                      | 0.15                       | 0.13                    |

Load, 7 lb. Speed, 1.73 ft. per min. Distance of travel, 104 ft.
Lubricant, white mineral oil

sliding parts in actual machines. As an example, the action of a piston ring in the cylinder of an internal combustion engine can be studied. The top ring is activated by irradiation in the neutron pile and inserted in the engine in customary fashion, the engine run for a period of time under specified conditions, and torn down for inspection. The walls of the cylinder were scrubbed clean of loose residue, and a sheet of film is slipped into the cylinder and pressed firmly against the wall by inflating a rubber bladder in the cylinder.

The resulting pattern of the metal transferred to the wall by the piston ring, shown in Fig. 5, bears a close resemblance to the commonly observed distribution of wear along a cylinder — that is, the transfer is heaviest near the top of the stroke, diminishes toward the





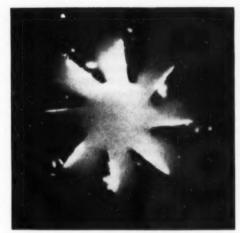


Fig. 6 — Autoradiograph of End Milling Cutter After Machining Radioactive Steel Showing Build-Up of Metal at Cutting Edges. Radiograph enlarged 2.5 ×

middle, and increases again near the bottom position. This parallelism between transfer and wear suggests that transfer to the other surface may be an intermediate step in the formation of a loose wear particle. Similar tests (reported elsewhere) run under a wide variety of conditions have been a step toward a better understanding of the action of piston rings.

Another application to practical mechanical operations is a study of the built-up edge which forms on metal cutting tools. In one instance, the metal to be cut was made radioactive and then machined with a standard cutting tool. Autoradiographic examination of the tool tip yields evidence as to the nature of the built-up edge when various cutting fluids are used. Figure 6 is a rather striking autoradiograph of the cutting end of a new eight-flute end mill which had been used to cut the end of a radioactive steel specimen using carbon tetrachloride as the cutting fluid. It will be seen from the white patches along the cutting edges that a minute built-up edge is present even though nothing was visible under the optical microscope.

### MEASUREMENT OF WEAR

A somewhat different philosophy of the tracer technique application is not to investigate the fundamental mechanism of the friction and wear process as has been described so far but to use it as a tool for the quantitative measurement of wear under standard conditions. As such, it may have considerable advantage in certain

instances over the conventional methods of wear measurement employed heretofore. In this category is the work of Pinotti, Hull & McLaughlin on the wear of piston rings in an internal combustion engine.

They used a piston ring made radioactive in the manner previously described, but instead of studying the distribution of material transferred to the cylinder wall, they measured the amount of radioactive material collected in the crankcase oil as the run progressed by taking samples of the oil at definite intervals. This method had two distinct advantages over the conventional method of chemical analysis of oil samples for iron. First it was extremely rapid, readings being obtained in a matter of minutes after the sample was taken from the crankcase. Second, by supplementing it with chemical analysis of the oil for total iron, the amount of worn iron in the oil contributed separately by the ring and by the cylinder and other parts of the engine could be determined. This is obviously valuable in attempting to choose better wearing piston ring materials.

Others have recently shown that it is also possible to measure small amounts of wear by a procedure somewhat the inverse of the above. A very thin layer of the surface is impregnated with radioactive atoms, in this case the fission fragments from a material being bombarded by neutrons. The decrease in the activity of this layer as it wears off is studied. The method is limited to a given range of thicknesses, in their case from 10<sup>-5</sup> to 10<sup>-4</sup> in., but is quite sensitive in this range.

While this article does not attempt to cover exhaustively the use of radioactive tracer methods in studies of friction and wear, it is hoped that it may suggest new experiments to other workers and so lead to further increase in our knowledge of these complex surface phenomena.

Acknowledgment — Most of these studies were made possible by a research grant from the Chrysler Corp. That portion of the work dealing with nitrided surfaces was sponsored by the National Advisory Committee for Aeronautics. The neutron irradiation of the specimens referred to in this article was carried out by the Clinton Laboratory of the Monsanto Chemical Co. under authorization of the U. S. Atomic Energy Commission. The authors also acknowledge their indebtedness to the many investigators whose published reports on this subject were referred to during this study.

# Quick Patina on Copper, Brass or Nickel Alloys

Webster defines patina as (a) a film formed on copper and bronze by exposure or by treatment with acids, etc.; a fine natural patina has artistic value. (b) A surface mellowing or softening, as in color, with age or use.

Everyone is familiar with the beautiful green coloration seen on many roofs throughout the countryside where atmospheric conditions are conducive to its formation. Such patina also forms on statuary — as, for instance, the Statue of Liberty. Many architects and owners are partial to such color effects and would be

glad to obtain copper for roofing which had been colored in the mill, or would specify that the copper roof is to be colored after it is in place, if a good rapid process were available.

Many art objects, vases, and bowls of copper, brass, bronze or other copper alloys may readily be colored and the artificial patina will be fairly long-lived. Age-old customs are burying such objects in the barnyard manure heap or soaking them with urine.

The chemical reactions responsible for the natural patina are involved, and quite an extensive literature can be found regarding the subject. Natural patina seems to form most readily on copper, brass, bronze and other copper alloys along the seacoast where the metal meets a salt atmosphere and a minimum of sulphur or sulphur compounds. Copper which has taken on its natural patina at Atlantic City, for example, might, if transferred to the atmosphere prevalent in an industrial area contaminated with sulphur fumes, turn black due to the formation of copper sulphide. As a matter of fact, it has been observed that a new

copper roof installed in a large city will often first turn a dark or blackish color and then, after a few years, gradually take on its green patina.

As an illustration within the writer's personal observation, a church close to the Harlem River in New York City had a beautiful copper steeple which had developed the natural color. Due to damage by lightning it became necessary to repair one side of the steeple. New copper sheets were installed which, within two years, formed an unsightly blackish section. It required an additional 14 years of exposure for the patched section to arrive at the point where it was difficult to distinguish from the rest of the roof. Copper's affinity for sulphur at first prevailed against the oxidizing effects of the atmosphere but the sulphur compounds formed were ultimately converted to the beautiful green.

It is the writer's opinion, based on the examination of many exposed installations and samples, that all patina, whether natural or artificially formed, will ultimately assume a color or shade that is determined and controlled by the atmosphere to which it is exposed. Dust, fume and chemical nature of the atmosphere are the major influences.

Water Pipe — Copper or brass water pipe has long been the favorite of builders and owners of substantial homes. In recent years its popularity has increased vastly with the advent of flexible, thin walled, seamless tubing and easily soldered field joints — all of which cuts the labor cost of installation quite mark-

edly. Potable water in these pipes also causes a patina to form, an essential factor in the corrosion resistance of the metallic system.

In those communities where the water supply has a

low pH (is on the acid side) an installation of copper tubing or brass pipe may result in temporary discoloration of the bathtub or basin. This is especially true where a faucet is allowed to drip. Soon, however, the pipe will of its own accord form its natural protective coating. This coating, once formed on the inner surface of the pipe or tube, will then protect that installation from further corrosion and no further trouble from discoloration should be experienced.

Haase, in Germany, devoted considerable effort to developing a method of coating the inside of pipe previous to its installation. The subject has had much attention, especially from investigators abroad where water conditions are not as well controlled as in this country. Discoloration from copper or brass water systems in this country is the exception rather than the rule, and is usually caused by stray currents or by water-softening systems, improperly installed or operated. Copper and brass, when properly installed, have exceedingly high resistance to corrosion when handling normal water supplies.

Several processes have also been developed for artificially producing the green patina and some patents have been issued. Such processes require considerable manipulation and equipment, and are difficult and inconvenient to use on a copper roof in place.

### QUICK PATINA

Obviously there would be many advantages and much time might be saved if the copper, brass or bronze could be so treated that a patina would be formed before the metal is installed in service, especially in roof, piping, gutters or leaders. For ornaments the process to be described seems ideal. As previously stated, this patina will protect the underlying metal and will, depending upon the local atmospheric or water conditions, quickly change to the stable coating which would be formed under normal conditions. If, for instance, atmospheric conditions are such that a pleasing coloration will not form but that the metal will ultimately turn black, then this artificial patina will also turn black and be of no use.

It is suggested that a solution containing

I lb. per gal. of commercial cupric nitrate dissolved in water be used for brass, commercial bronze or other copper alloys where there is an appreciable zinc content. For copper or its low-zinc alloys

a solution containing 0.75 lb. of commercial cupric nitrate plus 0.25 lb. of zinc nitrate in 1 gal. of water should be used.

William G. Schneider

Consulting Engineer

Milwaukee

A test of these solutions may readily be made. The metal sheet as it comes from the mill (without further cleaning) is heated to 230°F. (275° max.). In the laboratory a thin asbestos pad can be placed over a gas burner and the copper sample put on the pad. It can be checked for temperature much as a housewife checks an iron; when the metal sizzles under a wet finger it is right! The solution is then brushed or swabbed on.

It is essential that the temperature be high enough so the metal will sizzle when the solution is applied, and further that the metal be maintained at this temperature while the solution is being applied; otherwise, the results will not be uniform on a piece that is not uniformly heated. If the temperature is too high a black, dirty color will result. However, if this occurs the swabbing should be continued and as the temperature falls the green patina color will develop. The sample may be given several coats of solution while still on the hot plate.

As soon as the sample has taken on the greenish color it may be removed from the heat and washed with water. The coating will be hard and will not rub off on the fingers.

With a little practice very beautiful results may be obtained. Sheets measuring 24 x 36 in. have been handled in the laboratory with excellent results.

The temperature has been given as from 230 to 275° F. merely as a guide. It should be high enough for coloration, but overheating should be avoided so annealing effects are kept at a minimum.

If the metal has a coating of oil or is dirty, it is not necessary to clean it, as such adherents help to produce unusual effects.

In practice, large sheets would be sprayed as they issued from a heating furnace, using several nozzles. It would be necessary to gage the heat so that the solution does not quench the metal below the point at which the patina color is formed. Tubing can be heated with an arrangement such as is used on the Snead annealer and the solution can be fed to the inside of the tube by another smaller pipe having perforations.

Addition of zinc nitrate to the solution is not essential for copper; excellent results have been obtained when using cupric nitrate alone. Commercial cupric nitrate was found to give better results than the technical grade.

After the formation of the patina color the sample may be washed in a solution of 4 oz. of sodium hydroxide to the gallon of water. A blue color will then result, the depth of blue depending upon the length of time the sample is left in the solution. If the sodium hydroxide solution is too strong, results will be poor; if too weak, it will take too long a time to produce results. With a 4-oz. solution the time required is about 15 min.

Patina has been satisfactorily formed by the foregoing means on nickel and monel as well as copper and copper alloys. However, the manipulation of these metals necessitates somewhat greater care, because they tend to overheat, resulting in the formation of the black discoloration. Samples exposed to an atmosphere such as prevails in Washington, D. C., yielded good results over a period of three years. Samples exposed to salt air at the seacoast had a tendency to fade but the natural patina quickly re-formed.

It is recommended that anyone interested in using the process for other than ornamental purposes (indoor exposure) try variations of the solutions and temperatures and then conduct proper exposure tests. An important point to bear in mind is that no patina is permanent in its original state for conditions other than those under which it is formed.

The patina formed by the foregoing method acts as a stop-gap to corrosive action in the time between the erection of the metal and the conversion of its surface to the patina stable under the conditions under which it must serve. In this transition period — sometimes as long as several years — the coloration is much more uniform and pleasing than when similar metal is erected with the ordinary finish given to mill products.



The Throne of Dagobert Provides an Excellent Example of the Durability of Patina. This antique bronze chair (preserved at Bibliotèque Nationale in Paris) dates back to the 12th Century

### Correspondence\_

### Age Hardenable High-Nickel Alloys

CORVALLIS, ORE.

In the April issue of Metal Progress W. A. Mudge reports (p. 529) the age hardening properties of various high-nickel alloys. His summary, as a statement of facts, is of value for users of the materials. However, the research metallurgists would like to have some information as to the causes of the age hardening of these alloys, at least as far as it can be explained by their chemical analysis.

As quoted in the table of nominal properties (p. 530) the analyses approach or exceed 100% for all the alloys except one. The alloying elements might to some extent explain the structural hardening of "K" Monel, "KR" Monel, "S" Monel and Duranickel (which contain enough aluminum or silicon) or of Inconel "X" (which has enough titanium) for solution treatments, but this reason cannot be given for the aging of Permanickel. The titanium present in this alloy (0.4%) is low and it is probably tied up with the 0.25% carbon, showing as inclusions of carbide in the microscope, so that this element has to be ruled out as a cause for age hardenability. The total of the analysis quoted comes to 99.63%. It would be interesting to know what constitutes the balance. Perhaps a figure for magnesium content of these alloys would give some clues.

W. J. KROLL Consultant

### Passivity of Type 304

CONSHOHOCKEN, PA.

While engaged in a plant investigation, the writer had occasion to run corrosion tests on three heats of Type 304 stainless steel (18-8) in a hot (140 to 180° F.) 15% (by volume) aqueous solution of sulphuric acid containing about 1.25% sodium chloride. In the course of these tests, some curious phenomena were observed which the writer suspects may be new:

 Corrosion rates on specimens from two heats supplied by the same vendor were greatly reduced (inhibited) in the above solution in contrast to the corrosion rates shown by the same specimens in a hot, saltfree sulphuric acid solution of identical concentration. This was true for sensitized as well as for annealed specimens. These specimens became black during

exposure to the salt-free acid, and tended to remain so in the acid-salt solution. Curiously, annealed specimens from a third Type 304 heat of unknown manufacture, corroded at a rapid rate in the hot, acid-salt solution.

2. When re-immersed in hot, salt-free, 15% sulphuric acid solution after having been exposed to the hot acid-salt solution, the annealed specimens of the first and second heats were passive and, in contrast to their previous blackened condition, they soon became clean and bright. A sensitized specimen of one of these, likewise exposed to the hot acid-salt solution, did not become passive and brighten when re-immersed in the hot, salt-free, acid solution but, on the contrary, resumed approximately its original rate of dissolution. The annealed specimens from the third heat similarly did not become passive upon re-immersion in the straight acid solution.

3. Surface blackening by exposure of these stainless steels to the hot 15% sulphuric solution prior to immersion in the acid-salt mixture was apparently necessary to produce passivity upon re-immersion in the hot acid solution. One specimen, exposed to the acid-salt solution alone, showed inhibited attack but did not blacken; it failed to passivate when later immersed in straight 15% sulphuric acid.

4. Stability of the passivated surfaces of these steels in the hot acid appears to be a function of solution temperature and time of previous exposure to the hot acid-salt mixture. One specimen passivated for 1.4 hr. in the acidsalt solution remained passive for 3 hr. in the straight sulphuric solution at temperatures of 150 to 170° F.; passivity broke down at 170° F. Another remained passive for 70 hr. at temperatures averaging between 158 and 178° F. after exposure for 45 hr. to the hot acid-salt solution; passivity in this case broke down above 182° F. A third specimen passivated for 118 hr., remained unattacked by the straight sulphuric acid solution for 24 hr. at 163 to 172° F.; subsequent heating of the solution did not break down passivity until at least 208° F. was reached, above which strong attack ensued.

The writer suggests the shaky hypothesis that the passivation phenomenon exhibited by specimens from the two heats of Type 304 stainless steel is caused by the presence of residual molybdenum in the amounts of 0.18 and 0.17%, respectively. The third heat of 18-8, which did not show the passivation phenomenon, contains no molybdenum and, although nominally of Type 304, is high in carbon (0.09%) and chromium (20.90%). On the other hand, both annealed and sensitized specimens of Type 316 (18-12 with 2½% Mo), tested under the same conditions, showed inhibited attack in the acid-salt solution but did not become passive when re-immersed in salt-free acid. Perhaps the greater corrosion resistance of Type 316 to sulphuric acid prevented the formation of enough "corrosion product" to nucleate the passivation process.

REED KNOX, JR. Research Metallurgist Alan Wood Steel Co.

### Chemical Spot Tests for Nickel and Molybdenum

AURORA, ILL.

Considerable skill is required to identify different alloy ranges in mixed steels by spark testing even if standard reference pieces are available. We frequently use chemical spot tests for nickel and molybdenum. However, we have found that scaled and shotblasted surfaces may give erroneously high indications for these two alloying elements.

Some months ago we had forgings of 1045 steel which gave erratic results in heat treatment. These were checked for nickel on clean shotblasted surfaces and found to give strong tests. Later, the parts were rechecked on ground surfaces and gave no test. No tests were made for molybdenum on these forgings.

More recently another group of parts made of 3-in. round 4140 steel gave abnormal hardness when heat treated. Strong spot tests for nickel were obtained on shotblasted surfaces but very faint tests resulted on ground surfaces. Checking the blasting shot showed no indication of alloy.

These experiences led us to believe that nickel was being concentrated on the surface of the metal during the time the scale formed. If nickel is concentrated by scaling, perhaps molybdenum is also. We, therefore, took a slice from the 3-in. round 4140 steel and two pieces of carbon steel and subjected them to scaling tests at 1700° F. until about 0.003 in. of metal was scaled from each surface. Chemical spot tests were made for nickel and molybdenum on shotblasted and ground surfaces.

The table at the bottom of the page gives the results for these samples as well as for two 1045 forgings, together with the analyses for specified and residual alloys.

Apparently, scaling during heating for rolling, forging, and heat treating causes a preferential oxidation of iron (similar to that obtained in an openhearth furnace) while the less readily oxidizable alloys diffuse ahead of the oxidizing iron to give an alloy-rich layer just under the scale. Shotblasting removes this surface layer far more slowly than does grinding or filing.

The nickel and molybdenum which diffused from the 0.003 in. of oxidized metal is probably concentrated below the scale in a zone less than 0.001 in. deep. It must be at least this thin or such strong tests would not be obtained by scaling off only 0.003 in. of metal. Since residual nickel and molybdenum are the rule rather than the exception in steels partially made from scrap, the nickel will probably average close to one-tenth of one per cent and molybdenum a few hundredths of one per cent.

The molybdenum spot test we use will detect 0.10% but not 0.05%. Our nickel spot test has a high phosphoric acid concentration which practically eliminates the troublesome brown discoloration that frequently confuses the test when less phosphoric acid is used. A

|                  | Analysis |                |         |         |         |              | CHEMICAL SPOT TESTS |                   |                      |                    |                    |
|------------------|----------|----------------|---------|---------|---------|--------------|---------------------|-------------------|----------------------|--------------------|--------------------|
| MATERIAL         |          |                | NALIS   | 13      |         | 20           | ALING               | N                 | ICKEL                | MOLYE              | DENUM              |
|                  | %<br>C   | %<br>Mn        | %<br>Ni | %<br>CB | %<br>Mo | Темр.<br>°F. | METAL<br>LOST       | GROUND<br>SURFACE | BLASTED<br>SURFACE   | GROUND<br>SURFACE  | BLASTED<br>SURFACE |
| 1045 forgings    | (0.49    | $0.70 \\ 0.73$ | 0.03    | 0.08    | 0.04    | -            | -                   | None<br>None      | Strong<br>Strong     | No test<br>No test | No test            |
| 3 in. rd., 4140  | 0.41     | 0.65           | 0.17    | 0.86    | 0.17    | 1700         | 0.003 in.           | Faint             | Strong               | No test            | No test            |
| 1½ in. rd., 1040 | 0.41     | 0.83           | 0.11    |         | 0.02    | 1700         | 0.003 in.           | None              | Moderately<br>strong | None               | Moderate           |
| n. flat, 1022    | 0.19     | 0.88           | 0.09    |         | 0.03    | 1700         | 0.003 in.           | None              | Moderately<br>strong | None               | Moderate           |

0.20% Ni content gives a faint but readily recognized test but 0.10% will usually give no indication.

The solutions and procedures employed in the molybdenum test are:

### Solution No. 1

25 ml. distilled water

20 ml. concentrated nitric acid

5 ml. 85% phosphoric acid

### Solution No. 2

10% hydrochloric acid

### Solution No. 3

25 g. stannous chloride 35 ml. concentrated hydrochloric acid.

Dilute to 100 ml. with distilled water, add a few pieces of metallic tin, keep in a dark bottle.

### Solution No. 4

5 g. sodium thiocyanate 95 ml. distilled water

Two drops of No. 1 are placed on the cleaned metal surface, followed a short time later by one drop of No. 2. When reaction seems complete a drop of the solution is transferred with a glass stirring rod to a piece of filter paper. One drop of No. 3 is placed on the spot followed by one drop of No. 4. The formation of an orange halo around the spot indicates the presence of molybdenum. This halo is larger and deeper colored with higher molybdenum concentration of the metal tested. Except that it acts somewhat more slowly, it frequently works equally well to start with a mixture of No. 1 and 2.

Only two solutions are needed when making the test for nickel.

### Solution A

400 ml. distilled water

300 ml. concentrated nitric acid

350 ml. 85% phosphoric acid

### Solution B

1 g. dimethylglyoxime

60 ml. glacial acetic acid

30 ml. ammonium hydroxide

10 g. ammonium acetate

One or two drops of A are placed on the cleaned metal surface. When bubbling practically stops a small piece of filter paper is placed on the spot and a drop of B is added to the wet spot in the filter paper. Formation of a red color indicates the presence of nickel. It is faint pink for 0.20% Ni to bright red for 2.00% or more. If the spot remains white, the amount of nickel present is likely to be well under 0.20%.

ELMER H. SNYDER ARTHUR H. KLEIN Chief Metallurgist Chemist Austin-Western Co.

### **Etching of Titanium**

URBANA, ILL.

It is difficult to develop the structure of titanium for microscopic examination. The literature advises hydrofluoric acid solutions for etching, but our experience indicates the following method of preparation is superior:

Manual polish through the usual 0000 papers.

 Electrolytic polish in a solution of one part perchloric acid plus 20 parts of acetic anhydride, with a current density of 1 ampere per square centimeter; 4 min. in the bath at 40° F. or below.

3. Etch in vigorously boiling 1% sulphuric solution for 4 min.

It is imperative that the specimen be etched promptly following electrolytic polishing. Standing for a few hours passivates the surface so that an adequate etch is not produced. Since the etching reaction is essentially one of solution of the metal, it produces some slight relief, and oblique illumination often enhances the contrast between individual grains.

HOLLIS P. LEIGHLY

Olin Industries Fellow for Titanium Research University of Illinois

### Hysteresis, a Ghost!

PITTSBURGH, PA.

Meet Hysteresis, our watchdog on duty in 3% silicon steel. When we found him, he was blind so we gave him an eye, and now he is guarding against an influx of coercive gremlins. Pedigree? Your gauss is as good as ours (ouch!). Picral etch. × 2000.

A. G. LEE and H. S. LINK Research Laboratory Carnegie-Illinois Steel Corp.



## Hardness Scale Selector for Steel

Accurate hardness measurement is dependent upon several factors, one being that the thickness of the specimen must be great enough so that only the metal of the specimen is tested and not metal of the supporting anvil. When the penetrator makes a pronounced mark on the opposite side of the specimen ("anvil effect"), it is an indication that the true hardness test of the specimen is not registered. It is essential, therefore, that the hardness test specified or used for inspecting any part be compatible with the section thickness tested.

To provide some means of selecting suitable

hardness scales, the chart shown on p. 80-B was prepared by Pratt & Whitney Aircraft division of United Aircraft Corp. It applies only to parts of nominally uniform metallographic structure (not carburized or decarburized)

and of nominally uniform hardness throughout. Other factors such as necessary width, degree of surface refinement and contour of surface (that is, plane or curved) have not been taken into account, it being assumed that these conditions are those which are required for accurate hardness testing.

The curves are based on the depth of indentation caused by the hardness test, as calculated from information contained in "A.S.M. Metals Handbook" and "Hardness and Hardness Measurements", by S. R. Williams and formulas supplied us by Wilson Mechanical Instrument Co. Depth of indentation caused by the minor as well as the major load was determined in the Rockwell tests, since total penetration is the sum of the two. Authorities agree that steel is affected to a depth approximately ten times the actual depth of penetration, so the indentation figure for a given hard-

\*Based primarily on the joint A.S.M.-A.S.T.M.-S.A.E. hardness conversion tables (p. 98 and 99, "A.S.M. Metals Handbook", 1948 edition), modified slightly according to conversion charts prepared by Wright-Patterson Air Force Base, Wilson Mechanical Instrument Co., and information from B. H. Heyer of Armco Steel Corp. ness and test was multiplied by ten to mark the minimum thickness of steel of that hardness that can accurately be tested by that method. For example, the sum of major and minor indentations for Rockwell C-30 is 0.0070 in.;  $10\times0.0070=0.070$ , C-30 is approximately equal to

Vickers 302. Plot 0.070 against 302 (Point X).

To improve the usefulness of the chart, approximate conversion values\* are given along the curves.

The use of the chart is explained on the chart itself (p. 80-B). A properly selected hardness test for a thin part or piece of stock should result in a penetration which does not produce a pronounced anyil impression on the underside of the specimen. Although this is a sign that the penetration has not been too deep for the thickness being tested, it has been observed that when a very slight mark is visible on the under-

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**Pratt & Whitney Aircraft** 

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side, accuracy of the reading is not affected significantly.

Actual hardness tests by the Materials Control Laboratory of Pratt & Whitney Aircraft on six months' receipts of soft steel sheet and

strip of varying thicknesses verified the chart in the low range (DPH 80 to 250). Random checks on steel specimens of varying thicknesses and covering a greater range of hardness showed a very close agreement with the calculated values. The chart has been used by the materials laboratories, the design department and the inspection department of Pratt & Whitney Aircraft for about five years to select proper hardness test methods for steels and as an approximate hardness conversion chart.

Hardness Scales Included on Chart

| MACHINE          | Major Load          | Type of Penetrator              |  |  |
|------------------|---------------------|---------------------------------|--|--|
| Brinell          | 3000 kg.            | 10-mm. tungsten<br>carbide ball |  |  |
|                  | 3000 and 1000       | 10-mm. hard steel ball          |  |  |
| Vickers (DPH)    | 50, 30, 10, 1 kg.   | Diamond pyramid                 |  |  |
| Rockwell standa  | rd (10-kg. minor le | oad)                            |  |  |
| Scale C          | 150 kg.             | Diamond brale                   |  |  |
| Scale A          | 60                  | Diamond brale                   |  |  |
| Scale B          | 100                 | da-in. steel ball               |  |  |
| Scale F          | 60                  | ra-in. steel ball               |  |  |
| Rockwell superfi | cial (3-kg. minor l | oad)                            |  |  |
| Scale 30 N       | 30 kg.              | Diamond brale                   |  |  |
| Scale 15N        | 15                  | Diamond brale                   |  |  |
| Scale 30 T       | 30                  | de-in. steel ball               |  |  |
| Scale 15T        | 15                  | √a-in. steel ball               |  |  |



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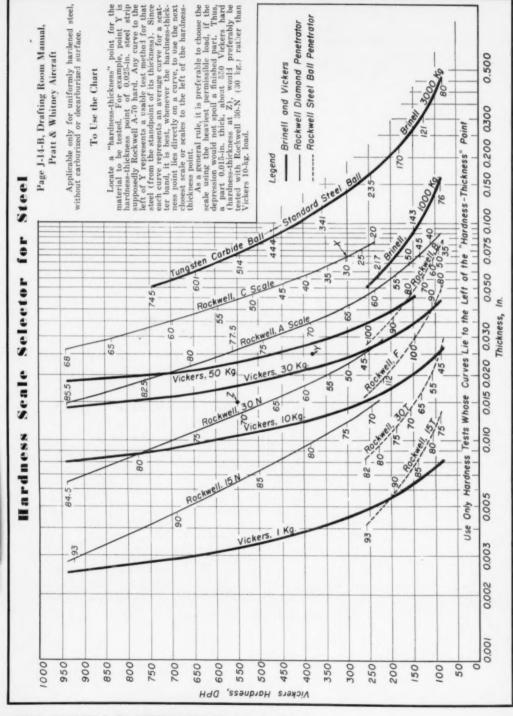
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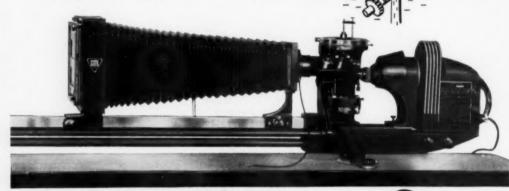
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# Strength of Pure Molybdenum at 1800 to 2400°F.

The present need for engineering materials having satisfactory properties when over 1800° F. has caused all promising materials to be thoroughly investigated. Molybdenum is one such; it is tough, dense, refractory; it melts at or above 4750° F. However, it has never been considered suitable for use at elevated temperatures other than in a vacuum or controlled atmosphere because of its poor oxidation resistance. Coatings have recently been developed that protect molybdenum from oxidation, and this will change the outlook.

Since little information is recorded concerning its strength properties at high temperatures, an investigation was started by the National Advisory Committee for Aeronautics. The work

was reported in Technical Note 2319 by the present authors, and the present article is drawn from that document.

Ductile molybdenum is now being economically fabricated by powder metallurgy methods and by arc casting. Our study was

on metal fabricated by powder metallurgy as follows: Pure molybdenum powder is cold pressed into bar compacts and then sintered in a reducing atmosphere at temperatures near the melting point. Sintering is followed by hot swaging and drawing or rolling. Swaging and other reduction methods, performed hot, are supposedly below the recrystallization temperature and therefore impart beneficial cold working effects which result in high strength and ductility at room temperature.

We used metal from two sources. Metal from one source originated as "ingots" weighing 5 kg. (11 lb.) and measuring 1½ in. square by 24 in. long. Manufacturer's analysis showed 0.01% iron, 0.015% nonvolatiles, balance molybdenum. Eight ingots were swaged to ¼ in., ½ in., ½ in. and 1 in. diameter, representing cross-sectional reductions of 96, 85, 70 and 38%.

Source B prepared \$\frac{9}{16} x \% x 24-in. ingots weighing a little over 3 lb. analyzing 0.005\% iron, 0.003\% carbon, balance molybdenum, from which rods \( \frac{1}{2} \) and \( \frac{1}{3} \) in. diameter were swaged, representing reductions from ingot of 44 and 86\% respectively.

From these rods test specimens were cut as shown in Fig. 1. The gage lengths were ground to smoothness of 5 to 16 rms. (root mean square in microinches).

Structure of Bars — Initial swaging of sintered molybdenum bars superimposed hot and cold working, resulting in complex structures. Although initial swaging is a high-temperature, manually operated forging operation with a reheat after each 10 to 15% reduction, and each reheat is at a progressively lower temperature, a limited amount of actual cold work occurs.

Continued working in the reduction of the 1-in. to the ½-in. bars greatly improved the metal's homogeneity; however, structural variables were not completely eliminated.

Figure 2 shows a typical cross section of a 1-in. bar, as swaged. Because swaging imparts greater deformations near the surface than at the center, recrystallization probably occurred

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**Lewis Flight Propulsion Laboratory** 

N.A.C.A., Cleveland

near the outer part of the bar during one or more of the reheats. Further swaging broke down these reformed grains, whereas in the center the deformation was cumulative. The core is noncircular because the

bar was swaged from a rectangular ingot.

An example of a strain gradient is shown along a radius at 7 o'clock. During swaging no recrystallization occurred in the central portion. The very large grains half way out indicate critical strain with limited deformation after recrystallization. The fine grains near the surface are different from those in the core, for higher magnification indicates severe fragmentation during working. Adjacent grains in the large-grained area that received similar amounts of deformation show considerable variance in strain markings under the microscope, which probably originated from prior grain orientation.

The core of this sample has the smallest grains encountered in this investigation, very similar in size to that of the ingot after sintering and before swaging. It also contains a multitude of very fine pores, their number always

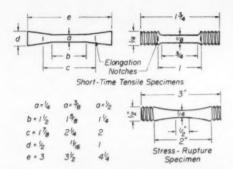


Fig. 1 — Test Specimens. Elongation marks were scribed as shown; elongation at fracture was measured after reassembling broken specimen

decreasing from the bar's center toward the circumference.

As-swaged structures of the ½-in. bars were of two general types, and neither contained a core area. One was small grained throughout, whereas the other was large grained throughout. In both types the larger grains were found near the surface. These variations of structure are believed to have originated in the size of the original particle of powder, or to have been introduced by the swaging variables.

### INFLUENCE OF SPECIMEN SIZE AND LOCATION

In swaging, the metal adjacent to the surface receives more work than the metal in the center of the bar. If this imparted considerably different mechanical properties to the material in the center, the data obtained from a small tensile specimen would not be representative of the entire cross section of a larger bar.

To determine size effects, a \$\frac{11}{16}\$-in. bar was chosen because it had been swaged a sufficient amount (70%) so the working effect reached the center, because specimens of smaller size could readily be cut from it, and because it recrystallized above 2400° F. (the maximum temperature of this series of tests). It had a typical structure consisting of elongated, severely strained grains, slightly more "fibrous" near the circumference of the bar, but fairly uniform in size and shape across the diameter of the bar. Figure 3 is a typical structure after testing at 2200° F. — it having been unchanged from that of the original as-swaged bar.

Tensile bars with test sections ½, ¼, ¾, ¾ and ½ in. in diameter were cut from the above, representing 3, 13, 29 and 51% of the original cross section, and each size was tested at 1800, 2000, 2200 and 2400° F. Strengths varied within

a range of about 3500 psi. at both room and elevated temperatures, which range is within material variations. If a difference in strength does exist from the center to the outside, it is too small to detect. Actual figures are:

| , | TEMPERATURE | MAXIMUM     | MINIMUM     |
|---|-------------|-------------|-------------|
|   | Room        | 90,550 psi. | 87,680 psi. |
|   | 1800° F.    | 33,650      | 32,500      |
|   | 2000        | 29,700      | 26,700      |
|   | 2200        | 28,500      | 25,650      |
|   | 2400        | 27,350      | 23,700      |

No difference in hardness was perceptible from the center to the circumference of the swaged bar. Rockwell A hardness readings varied from 53.5 to 56.0, with no definite pattern.

The effect upon ductility could not be determined from the elongation values because the ratio of length to diameter of test section varied from 2.5 to 6. Fractures were similar. Because fracture type, tensile strength, and hardness did not vary appreciably with test-section area, it is believed that ductility would also remain essentially constant.

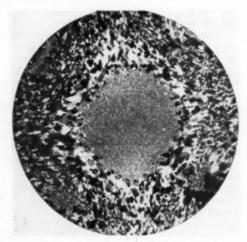


Fig. 2 — Transverse View of 1-In. Swaged Bar, Showing Flow Lines.  $3 \times$ 

### HIGH-TEMPERATURE FURNACE

It would be well to pause for a brief description of the furnace for making such high-temperature tests as just noted. A drawing is shown in Fig. 4. All metal parts used within the heating zone of the furnace were fabricated from Inconel X. Because molybdenum oxidizes rapidly in air at 1200° F., a metal tube was placed around the tensile specimen, and a

sufficient flow of helium introduced to exclude excessive oxygen. For stress-rupture experiments a protective atmosphere of argon gas and Haynes Stellite No. 25 alloy grips proved satisfactory, since an atmosphere-protection tube was placed around the rupture specimen and recessed at both ends into the grips. This afforded constant atmosphere protection while the specimen was elongating.

Preliminary rupture testing with Inconel X grips and helium gas for a protective atmosphere proved unsatisfactory. Severe corrosion of the molybdenum occurred where it was in contact with or closely adjacent to the Inconel X in an atmosphere of helium.

Temperature of the specimen and the furnace was controlled by a thermocouple placed against the test section. Temperature was maintained to  $\pm 3^{\circ}$  F. in the tensile tests,  $\pm 5^{\circ}$  F. in the stress-rupture tests. Preliminary tests with four thermocouples showed a maximum varia-

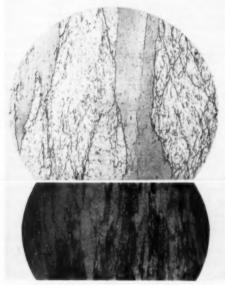


Fig. 3 — Typical Microstructure at 150 and 25 Diameters of Bar Hot Swaged 70%, After Testing at 2200° F.

tion of ±3° F. over the gage length of the test specimen.

It took from 1¾ to 2½ hr. to reach temperatures of respectively 1500 to 2400° F. in this furnace, and specimens were soaked for 30 min. Loading rate in the short-time tensile tests was

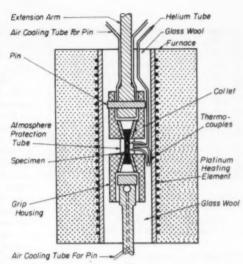


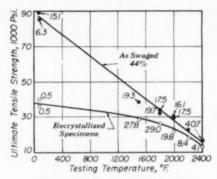
Fig. 4 — Apparatus for High-Temperature Tensile Tests. Furnace has firebrick covers on both ends. Metal parts are of Inconel X

about 2500 lb. per min. up to the yield point. Above this load, the rate of loading was increased as rapidly as possible to eliminate possible short-time stress-rupture factors and to prevent serious deformation of the gripping mechanism. Since the rate of strain beyond the yield point was not controlled, the elongation values are probably influenced by this factor.

### EFFECT OF RECRYSTALLIZATION

A series of 1/2-in, bars from the second source (44% reduced by swaging) were machined into tapered test bars with 1/4-in. diameter test section. Half were tested in the condition as received; the other half after recrystallization (heated 48 hr. at 2400° F.). Recrystallization has a detrimental effect upon the ultimate tensile strength both at room and elevated temperatures (Fig. 5). Figures alongside test points represent per cent elongation in 1.5 in. It will be noted that the recrystallized bars had practically no ductility at room temperature and broke with fracture Type 5 (see Fig. 12). As-swaged specimens tested at room temperature had fair elongation, even though the nature of the fracture was either Type 5 or 6 (Fig. 12 and 13), and they retained good values at high temperatures. Recrystallized bars had good ductility when tested at 1500 to 2000° F, with fracture Type 2 (Fig. 9), but elongation fell sharply at higher temperatures.

It appeared, therefore, that recrystallization



Effect of Recrystallization on the Ultimate Strength and Elongation in 1.5 In. of 1/4-In. Test Specimens Pulled at High Temperature

lowered the tensile strength of molybdenum at all temperatures. Recrystallized metal was quite ductile at elevated temperatures but extremely brittle at room temperature. Recrystallized metal exhibited an intergranular fracture at

52

48

0001

Alloy

room temperature; from 1500 to 2000° F. fracture was predominantly transgranular; above 2000° F. the fracture reverted to the intergranular type.

Preliminary recrystallization studies were limited to 1 hr. at temperature. The temperatures were lowered and heating periods lengthened to a maximum of 75 hr., to simulate possible hightemperature service conditions. Recrystallization

\*Lines for titanium carbide from N.A.C.A. Technical Notes No. 1911 and 1915. Incone! X (N.D.R.C. 99) is a 70-15-7 Ni-Cr-Fe with 1.0% Cb, 2.5% Ti, 0.7% Al, 0.20% Cu. 0.08% C. 0.65% Mn. 0.50% max. Si. Data are from book issued by International Nickel Co., Jan. 1949. Alloy 422-19 (N.D.R.C. 12, or Haynes Stellite No. 30) is a cobalt-base alloy with 26% Cr. 15% Ni. 6% Mo. 2.0% max. Fe, 0.40% C, 0.5% Mn and 0.5% Si. Data are from book issued by Haynes Stellite Co., 1948.

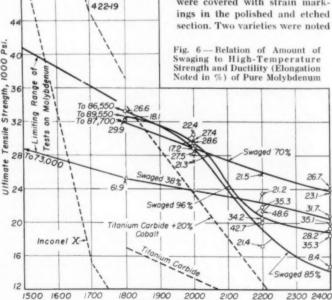
was sluggish because the degrees of "effective" cold work varied considerably. (By "effective" is meant the amount of cold work that induces recrystallization which in turn affects the strength properties.)

We have two structures to examine in the larger bars: First, the core, which was converted to a wellequiaxed grain of somewhat smaller size within 24 hr. at 2800° F. Second, the large grains just outside the core did not change much in shape, area or contrast when viewed at 13 and 150 diameters, but after 24 hr. at 2800° F. the severe strain markings so prominent in the as-swaged grains almost disappeared. absence or near absence of these markings indicated either recrystallization or stress relief. Recrystallization is always evident, microscopically, by grain re-formation; however, the large grains did not re-form, as remarked above.

In a further attempt to classify these large reheated grains, a microhardness survey was made with Knoop indenter and 2-kg. load: KNOOP HARDNESS NUMBER

| Severely strained, as-swaged grains | 220 |
|-------------------------------------|-----|
| Same, after 24 hr. at 2800° F.      | 212 |
| Smooth, as-swaged grains            | 209 |
| Same, after 24 hr. at 2800° F.      | 213 |
| Recrystallized grains               | 184 |

A rather complete micrographical study of the 1/2-in. bars was made. These bars in longitudinal section consisted of elongated grains, almost all of which were covered with strain markings in the polished and etched section. Two varieties were noted



Temperature, °F.

in the as-received stock: one was predominantly fine grained, the other was coarse grained. Recrystallization began in the fine-grained structure after 1 hr. at 2000° F. and was complete except near the surface of the bar after 20 hr.; the coarsegrained structure required 20 hr. at 2000° F. for beginnings of crystallization to be noted, and 20 hr. at 2200° F. was required for its completion. Recrystallization consistently began in the bar center and progressed to the surface. Under the microscope the recrystallized grain sizes are closely similar to, and also retain some of the directionalism of, the asswaged grain sizes.

Often a small but varying amount of similarly fragmented areas did not recrystallize. Because such areas appear to have been severely fragmented, they should re-form readily, but much higher temperatures and soaking times were necessary to recrystallize them.

### HIGH-TEMPERATURE STRENGTH

Figure 6 gives high-temperature, short-time tensile tests on bars swaged various amounts. It will be observed that a 1/2-in, test piece cut from a 1-in. bar (swaged 38% from ingot size) is considerably weaker at room temperature (73,000 psi.) than others swaged more heavily. From 1800 to 2400° F. its strength was also about 20% less than the bar swaged 70%. The uniform decrease in strength with increasing temperature indicated absence of effective recrystallization. Ductility was very good at 1800° F. or higher. From 75 to 100% of the test specimen's cross section consisted of the central core of fine-grained material, similar to that shown in Fig. 2. The grains were rather uniform, a mixture of fine, strained and fragmented grains with only slight directionalism. Recrystallization studies indicated a 1-hr. recrystallization temperature of approximately 2825° F. for such material.

Figure 6 also shows that the bar swaged 70% and tested with a 3/4-in, section has a

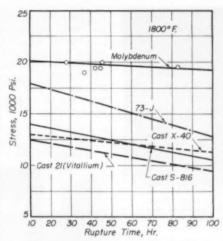


Fig. 7 — Stress-Rupture Life\* of ½-In. Wrought Molybdenum Bars at 1800° F., in Comparison With Several High Alloys. Three test results for molybdenum are for longer times: 116 hr. at 19,500 psi., and 141 hr. and 267 hr. at 19,000 psi.

straight-line plot, and therefore also did not recrystallize during high-temperature testing. (Auxiliary studies showed its 1-hr. recrystallization temperature to be about 2500° F.) Fractures were all Type 1 (Fig. 8). Elongations, though good, were less than those recorded for the larger bar.

The bar swaged 85% and tested with a ¼-in. section showed a rapid drop in strength between 2000 and 2200° F. and a less rapid drop as 2400° F. was approached. This rapid rate of change of strength was caused by the "effective" recrystalization of the metal during testing. Its ductility was good at 1800 to 2200° F., but fell off consider-

ably at 2400° F., where it had Type 4 fracture (Fig. 11).

While the material swaged 96% and tested in  $\frac{1}{8}$ -in. section recrystallized similarly, it has uniformly high ductility (elongation). Its elongation at room temperature (26.3%) is especially noteworthy since the other three series of bars with lower reduction by swaging had practically no elongation at  $70^{\circ}$  F.

\*Editor's Note — This line is unusually flat in slope. Furthermore, it is considerably higher than the results reported by Parke on p. 95 of Metal Progress for July 1951.

Vitallium (Haynes Stellite Alloy 21, or N.D.R.C. 10) is cobalt base and contains 0.3% C, 1.0% Mn, 0.6% Si, 2.0% max. Fe, 27.5% Cr, 5.5% Mo and 2.5% Ni.

X-40 (Haynes Stellite Alloy 31, or N.D.R.C. 71) is also cobalt base and contains 0.5% C, 0.6% Mn, 0.7% Si, 1.5% max. Fe, 2.5% Cr, 7.5% W and 10.0% Ni.

Data for both the above are quoted from Haynes Stellite Co.'s 1948 publication "Haynes Alloys for High-Temperature Service".

73-J is an experimental casting alloy, cobalt base, containing 0.73% C, 1.0% Mn, 23.0% Cr, 6.0% Mo, 6.0% Ni and 2.0% Ta.

Cast S-816 (N.D.R.C. 76) is considerably stronger than when forged. Its chemical analysis is 0.40% C, 0.6% Mn, 0.3% Si, 20.0% Cr, 3.0% Mo, 4.0% W, 20.0% Ni, 45% Co, 4.0% Cb, balance Fe.

Data for 73-J and S-816 are quoted from Grant, Frederickson and Taylor, *The Iron Age*, March 18, 1948, p. 73.

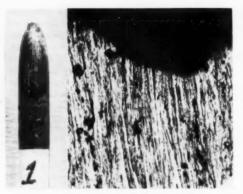


Fig. 8 — Type 1, Pin-Point Fracture; Transgranular With 70 to 90% Reduction in Area. In Fig. 8 to 13, test pieces are about full size; micros of fractured region 150 ×

This evaluation of as-swaged molybdenum indicates that swaging between 70 and 96% had a negligible effect on tensile strength at all temperatures below the recrystallization temperature. The effect of swaging upon lowering the recrystallization temperature, however, is pronounced and limits the usefulness of molybdenum at higher temperatures. Increased swaging reduction decreases room-temperature brittleness, but only if the swaging adds "effective" cold work to the metal.

### STRESS-RUPTURE IN 100 HR.

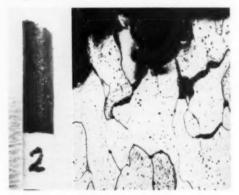
Stress-rupture tests were conducted at 1800° F. on test pieces (Fig. 1) cut from ½-in. diameter bars (swaged 85% from ingot). Results are shown in Fig. 7.

The 100-hr, recrystallization temperature of this material was in excess of 1800° F.; therefore, this variable did

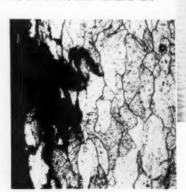
not affect the evaluation of as-swaged metal in the longest heating period (267 hr.).

Another lot of ½-in, bars from the same source was also tested for stress-rupture. This material was extremely heterogeneous; some bars contained hollow pipes and cold shuts. Micrograins were mixed in size, from fine to large, but no evident relation existed between amount of fine grains and rupture life.

Fig. 9 — Type 2 Fracture; Approximately 45° Shear, Either Transgranular or Intergranular With 10 to 40% Reduction in Area



The value of 19,300 psi, for the 100-hr, rupture life at 1800° F., taken from the logarithmic plot, could easily vary ±300 lb. because of the slight slope of the curve and because rupture life at any one stress could not be closely reproduced. Scattered values occurred



3

Fig. 10—Type 3 Fracture; (Right) Honeycombed Tear; Predominantly Transgranular With 50 to 99% Reduction in Area; Left Is Torn or Honeycombed Surface Along Test Piece

at all loads for all metal evaluated. Metallographic examination did not reveal any appreciable deviation in crystal structure.

It is important to remember that the good values in Fig. 7 are for as-swaged metal only. After recrystallization, its 100-hr. strength dropped to 10,000 psi. — practically half.

### DIRECTIONAL PROPERTIES OF PLATE

Rolled <sup>1</sup>4-in. molybdenum plate is an anisotropic material, but is strong and ductile in both the transverse and longitudinal directions. At all temperatures up to 2000° F. the tensile strength in the direction transverse to rolling is somewhat greater than in the longitudinal

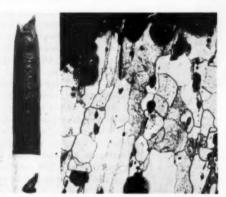


Fig. 11 — Type 4 Fracture; Tear; Predominantly Transgranular With Approximately 40% (Max.) Reduction in Area

direction; above 2000° F, the difference is within the error of testing.

|                         | STRENGTH | ELONGATIO? |
|-------------------------|----------|------------|
| Transverse at 70° F.    | 97,900   | 2.0        |
| Longitudinal at 70° F.  | 87,300   | 2.5        |
| Transverse at 1800° F.  | 40,650   | 14.5       |
| Longitudinal at 1800° F | . 35,200 | 30.1       |

At 2000 to 2400° F. the plate had strength about equal to the bars swaged 70% (Fig. 6) but elongations were considerably lower. The ductility in a direction normal to the surface, although not determined in this investigation, is known to be very low because of the brittle planes of weakness parallel to the surface.

Because of the rolling directionality, the tensile fractures were wedge-shaped below the recrystallization temperature, the sharp edge of the wedge being parallel to the rolling surface. Above the recrystallization temperature, the fracture changed to a rough tear type.

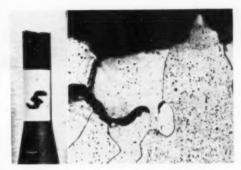


Fig. 12 — Type 5, Brittle, Transverse Fracture; Transgranular or Intergranular With Essentially No Reduction in Area

### FRACTURE TYPES

As-swaged and recrystallized bar specimens exhibited six distinct types of fracture at room and elevated temperature, as shown in Fig. 8 to 13.

Molybdenum from both sources showed similar types of fracture for both as-swaged and recrystallized material. The as-swaged metal, worked sufficiently to give a fairly uniform grain structure from the circumference to the center of the bar, had a transgranular fracture with good elongation at all temperatures up to recrystallization. Material which was only partly recrystallized before or during testing had a torn fracture that was a mixture of both transgranular and intergranular failure similar to Types 3 and 4 at temperatures above 2000° F. Type 3, with the honeycombed surface, appeared to be an intergranular separation at the surface, but fracture was predominantly transgranular.

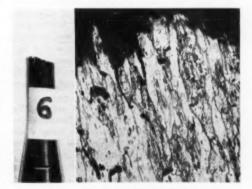


Fig. 13 — Type 6, Ductile, Transverse-Transgranular Fracture; 0 to 25% Reduction in Area

When molybdenum is fully recrystallized, fracture seeks the grain boundaries at both room temperature and at temperatures above 2000° F., resulting in an intergranular failure with low elongation. At temperatures from 1500 to 2000° F., the metal showed ductility as great as or greater than the as-swaged material. In this temperature range the fracture is predominantly transgranular. This change (reverting again to a much less ductile, intergranular fracture above 2000° F.) seems rather odd, but is borne out in part by work reported by W. P. Sykes in Transactions of the A.I.M.E., V. 64 (1919-1921).

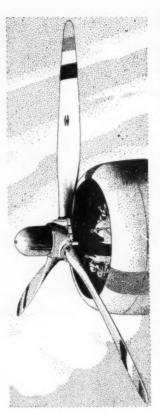
### RECRYSTALLIZATION

In evaluating the two manufacturers' products, a considerable variation was found in properties, particularly at elevated temperatures. Molybdenum from Source A had a fairly clean, uniform, fibrous grain structure in all the bar sizes except the 1-in. size. Fabrication was sufficiently uniform to produce

metal that possessed a progressively lower recrystallization temperature and a tendency toward higher strengths with increasing amounts of swaging. Molybdenum from Source B did not show any similar systematic change, nor did it possess nearly the uniformity of structure.

The heavily swaged metal of both manufacturers had a rather uniform, fibrous grain structure, but the material from Source B had a recrystallization temperature approximately 125° F. higher than that from Source A and recrystallization occurred over a greater range of temperatures.

Material from Source B that was lightly swaged (44% reduction in area) had nonuniform grain structure, and appeared to have some porosity. However, its strength below the recrystallization temperature was 20 to 35% higher than material from Source A that had received an equivalent amount of swaging. Moreover, it had a recrystallization temperature approximately 600° F. lower, which, strangely



enough, was about the same as for other metal from the same source that was swaged about twice as much.

The lightly swaged molybdenum from Source B had a grain structure that resembled recrystallized material much more closely than the fibrous, as-swaged structure found in other material. It was probably subjected to a temperature above recrystallization during the latter part of the swaging treatment for a sufficient time to cause full or partial recrystallization. Further swaging at lower temperatures might then produce some smaller fragmented grains. Possibly a large amount of previous effective swaging was lost when recrystallization occurred.

It is difficult to explain why the material still possesses excellent strength below the recrystallization temperature for the small amount of total ingot reduction. Therefore, total ingot reduction is not considered to be a criterion by which mechanical properties can be predicted.

### CONCLUSION

From these tests it is concluded that pure molybdenum, either as-swaged or recrystallized, has tensile properties at 1800 to 2400° F. equivalent to or higher than titanium carbide, with or without cobalt binder, or ceramic bodies. This is shown by appropriate lines in Fig. 6. At lower temperatures, up to 1500° F., molybdenum is weaker than other established alloys, like Inconel X and 422-19.

Stress-rupture properties at 1800° F., when tested in protective atmospheres, are much superior to several established alloys at that extreme temperature.

Since recrystallization has such a considerable effect on high-temperature strength properties, an extended investigation is under way at Lewis Flight Propulsion Laboratory to determine what is the cause of tardy and sluggish recrystallization in some of the test pieces we examined. If the recrystallization temperature of molybdenum could be increased, a corresponding advantage would ensue.



For the want of a nail the shoe was lost,
For the want of a shoe the horse was lost,
For the want of a horse the rider was lost,
For the want of a rider the battle was lost,
For the want of a battle the Kingdom was lost . . . .

## and all for want of

a nail"

BENJAMIN FRANKLIN, "Poor Richard," 1758

The fate of nations often hangs on little things. Take this rusty old nail. It symbolizes thousands of tons of worn-out machines and broken parts lying useless in our plants, factories, farms, and homes—scrap steel desperately needed today by our steel mills.

You can help make this nail, and all the other scrap you can collect, go to work again . . . in new steel for ships, tanks, and guns required for defense purposes.

So survey your plant now for every last bit of scrap.

Then get it to your scrap dealer promptly. This will
not only help assure the nation of the arms needed to preserve
our freedom, but it will also mean more steel
for your own products tomorrow.

### Personal Mention\_



Walter W. Edens

Unique in that he is a mechanical engineer with a master's degree in metallurgy, a research and production executive, WALTER W. EDENS . past chairman of the Milwaukee Chapter of the American Society for Metals, and current chairman of the Milwaukee Chapter of the American Foundrymen's Society, has been appointed Defense Projects Executive for Alloy Engineering and Casting Co. of Champaign, Ill. Here he will devote his full time to the Casting Potentials Project, a study for the Air Matériel Command, U.S.A.F., under general direction of H. H. Harris . Mr. Edens combines an academic and theoretical background in the castings and metal industries with unusual production experience, and will concentrate on devising methods whereby the foundry industry may cooperate more fruitfully with the aircraft industry. Mr. Edens received his M.S. degree from the University of Wisconsin in 1937, and spent the next ten years as chief metallurgist. foundry superintendent and technical director of Ampco Metal, Inc., of Milwaukee. Prior to his present appointment he was vice-president of Badger Brass & Aluminum Co.

Mr. Edens has been joined by Thomas G. McNamara . formerly chief metallurgist of Continental Aviation and Engineering Corp., Detroit, who has been appointed chief metallurgist at Alloy Engineering and Casting Co. Mr.

McNamara will also spend his time on the Casting Potentials Project, studying aircraft specifications and evaluating the status of castings supplied to the aircraft industry in terms of quality.

Alfred Strasser (3), formerly a metallurgical engineer for the special projects department, M. W. Kellogg Co., Jersey City, N. J., has taken a position as metallurgist in the technical analysis division of Wright-Patterson Air Force Base, Dayton, Ohio.

R. H. Lambert , formerly in the welding and metals branch of the Bureau of Ships, Navy Department, Washington, D. C., has been transferred to the Philadelphia Naval Shipyard where he is shop superintendent for the production department.

Martin J. Holleran has been named assistant manager of tool steel sales by the Carpenter Steel Co., Reading, Pa. He joined the company in 1946 and served as sales engineer out of the New York City Mill-Branch Warehouse until his recent promotion.

Philip J. Duffy (a), a member of Lindberg Engineering Co. for the past 12 years, is now operating as district sales and service manager for Lindberg's new office in Atlanta, Ga.

Roy F. Bourgault a has accepted a position as research associate in the Department of Metallurgy, Stevens Institute of Technology, Hoboken, N. J.

Richard L. Nyquist has been employed by MacDermid, Inc., Waterbury, Zonn., as a trainee in the sales department.

Kenneth D. Kelly (2) has accepted a position with the Oil Well Supply Co., Oil City, Pa., where he is on the training program which leads to the foundry metallurgy department. He graduated from Grove City College, Grove City, Pa., in June.

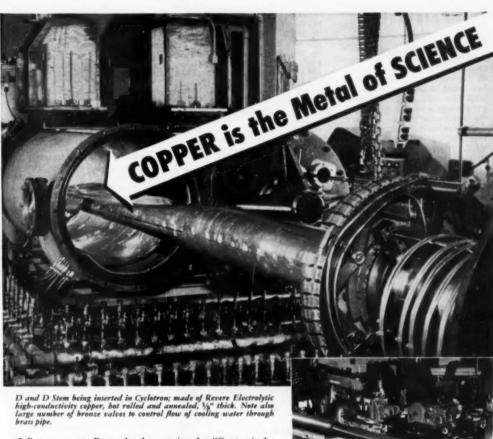
Richard B. Wagner is now active as a consulting engineer, specializing in the field of metallic coatings.



V. A. Crosby

VICTOR A. CROSBY . metallurgical engineer for Climax Molybdenum Co., in charge of sales, service and development in the Detroit area, was awarded the 1951 John A. Penton Gold Medal by the American Foundrymen's Society "for outstanding service and contributions to the ferrous foundry". Crosby ("Vic" to most everyone, including his wife) was born, raised and educated in the State of Mississippi, a circumstance which permanently warped his accent. He intended to be a sugar chemist, but instead (after discharge from the Air Force in World War I) became foundry metallurgist for Packard in Detroit and later for Studebaker in South Bend. He joined Climax in 1934. Vic has traveled widely, addressed numerous chapters of the A.S.M. and the A.F.S. on various aspects of foundry practice, alloyed cast irons, and castings for particular industries and uses. He has been chairman of the Detroit Chapter of the American Society for Metals and the American Foundrymen's Society, chairman of the division on automobile castings of the Society of Automotive Engineers, and active in handbook work for all of these organizations.

Edward N. Case thas been appointed product supervisor for metal trades product sales in the synthetic organic chemicals department, Industrial Chemicals Division, American Cyanamid Co., New York. He was formerly group leader of the company's metal trades laboratory, Technical Service and Development Division, Stamford, Conn.



◆ For many years Revere has been saying that "Copper is the metal of invention." It has high electrical and heat conductivity, excellent resistance to corrosion, is easily fabricated and formed, so that it is attractive to designers and inventors, as well as to manufacturers. Now we say it is also "The metal of science," because it is so essential to the operation of most scientific devices.

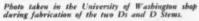
The pictures on this page illustrate some of its uses in a cyclotron, built by and for the Nuclear Physics Laboratory of the University of Washington in Seattle. The instrument was designed and constructed so far as possible by University personnel, who were completely successful in working copper into the most complicated shapes.

Revere collaborated on the project in various ways, and furnished copper bar, sheet, rod and tube to the University's high specifications. Remember that Revere will be glad to consult with you on your problems concerning copper and copper alloys, and aluminum alloys.



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Seven miles of Revere copper bus bar were wound into great coils for the cyclotron electromagnet. The University built the winding machine itself, and wound the coils in its own shop. The special Revere bar is soft temper, free from scale, with rounded edges.

### Personals

John T. Burwell, Jr., (2), formerly associate professor of mechanical engineering, Massachusetts Institute of Technology, Cambridge, Mass., has taken a permanent position with Horizons, Inc., Cleveland. Dr. Burwell served in the Office of the Coordinator of Naval Research and Development from 1942 to 1946, on leave of absence from M.I.T. He is the author of the 20 book, "Mechanical Wear".

Robert C. Shnay (a), who finished his graduate degree requirements at the University of British Columbia last June, has been employed by the Department of Mines, Physical Metallurgy Division, Ottawa, Ont., as a research engineer.

William E. B. Mason has transferred from his position as inspector-supervisor at the Toledo Refinery, Pure Oil Co., to that of assistant quality control engineer for the American Locomotive Co., Dunkirk, N. Y.

Daniel L. Weller has been working as a shift metallurgist at Crucible Steel Co. of America, Sanderson-Halcomb Works, Syracuse, N. Y., since he graduated from Carnegie Institute of Technology in June.

E. J. Walker (a), who has been foreman of experimental heat treatment in the main laboratory, Bethlehem Steel Co., Bethlehem, Pa., is now experimental engineer in the metallurgical department.

Robert L. Sauer , formerly job evaluation engineer for Timken Roller Bearing Co., Canton, Ohio, is now associated with Westinghouse Electric Corp., Headquarters Division, Pittsburgh, as a staff industrial engineer.

Randall E. Britt has accepted a position with Howard Foundry Co., Chicago, in the Magnesium Division. He was formerly employed by the Engineer Research and Development Laboratories, Fort Belvoir, Va.

Harry J. Weil has been employed as a metallurgical engineer by the Phillips Petroleum Co., Bartlesville, Okla., in the test division of the engineering department, since his graduation from Lehigh University last June.

John A. Milko that taken a position as metallurgist at Oak Ridge National Laboratory, Oak Ridge, Tenn., where he is employed on the alloy development program of rare earth metals.

T. Roy Evans (a), a June graduate from Missouri School of Mines, has accepted a position as engineer to do titanium development work at E. I. duPont de Nemours & Co., Inc., Wilmington, Del.

Clayton L. Nelson (3) has been transferred from his position as assistant resident engineer at the Flint, Mich., plant to the position of associate resident engineer at the Tonawanda, N. Y., plant of the Chevrolet Motor Division, General Motors Corp.

David B. Ballard , who graduated from Virginia Polytechnic Institute last June, has been employed as junior metallurgist at National Bureau of Standards, Metallurgical Div., Washington, D. C.

Harold Meese (2) has been recalled to active duty with the Navy and is assigned to duty with the Office of Naval Material, Washington, D. C.



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- high fatigue resistance and improved corrosion resistance
- an extremely hard, wear resistant surface
- · excellent core properties
- no distortion

The Nitralloy Corporation licenses its exclusive new nitriding process directly to furnace owners and larger users of nitriding steels without limitation as to the source of the steel nitrided. Purchasers of Nitralloy® steels from any of the following licensed steel producers and distributors automatically acquire the right to use the process in converting steel so purchased. Write to them, or directly to us, for complete details of the properties of Nitralloy and the adaptation of your present nitriding facilities to the improved nitriding procedure.

Atlas Steels Limited, Welland, Ont. \* The Babcock & Wilcox Tube Co., Beaver Falls, Pa. \* Copperweld Steel Company, Warren, Ohio \* Firth-Sterling Steel Co., McKeesport, Pa.\* \* Grede Foundries, Inc. (steel castings), Milwaukee, Wis. \* Ratary Electric Steel Co., Detroit, Mich. \* Vanadium Allays Steel Company, Pittsburgh, Pa. \* Joseph T. Ryerson & Son, Inc., Chicago, Ill.\*\*; Clincinnati and Cleveland, Ohio; Persey City, N. J.\*\*\*; Beston, Mass.; Detroit, Mich.; St. Louis, Mo.; Philadelphia, Pa.; Buffalo, N. Y.; Milwaukee, Wis.; Los Angeles\*\*\* and Oakland, Calif.; Houston\*\*\* and Dallas, Texas.

\* Patent No. 2,437,249

" " Nitrard steel only

\*\*\* Nitralloy stocked at these warehouse

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### Personals

Charles O. Hlavacek has been employed as a laboratory investigator in the main laboratory at Bethlehem Steel Co., Bethlehem, Pa., since his graduation from Michigan College of Mining and Technology in March.

Vernon H. Jones 🖨 has been employed by Hayes Steel Products Ltd., Merriton, Ont., as a metallurgical engineer. Keki K. Irani is now working in the openhearth department of the Granite City Steel Works, Granite City, Ill.

Roy H. Curtis (5), June graduate of Carnegie Institute of Technology, is now employed as a student engineer, Chrysler Institute of Engineering, Detroit.

Byron F. Campbell (2) has been appointed executive engineer for Harry Ferguson, Inc., Detroit. He has been chief of the company's laboratories for the past six years.

David L. Zimmerman has accepted a position as technical graduate on the rotational training program, General Electric Co., Hanford Works, Richland, Wash. He graduated from the University of Wisconsin last June.

W. R. Hibbard, Jr., , has taken a new position in the research laboratory at The Knolls, General Electric Co., Schenectady.

George D. Cremer (a), formerly resident consultant to the Oak Ridge National Laboratory, Metalurgy Division, has taken a position with the Research Division, Solar Aircraft Co., San Diego, Calif.

Arnold G. Mosier , who recently graduated from the Colorado School of Mines, has been employed as an analytical chemist by the Colorado Analytical Uranium Ore Project, Grand Junction, Colo.

Harold G. Bowen, Jr., . has been head of the Armor, Projectile, Bomb, Ballistic, Rocket and Guided Missile Warhead Branch, Research and Development Division, Bureau of Ordnance, Washington, D. C., since completing the senior course in strategy and tactics at the Naval War College, Newport, R. I.

Kenneth D. Morland has been promoted to acting principal surveyor of American Bureau of Shipping's Chicago office.

Willard H. Hawley, Jr., (3), a recent graduate from Yale University, has been employed by the Navy Department, Bureau of Ships, Washington, D. C.

John L. Blazich has accepted a position as plant superintendent with Shippers' Car Line, Inc., Mitton, Pa. He was formerly assistant engineer in the improvement section, American Car and Foundry Co., New York.

Charles R. Johnson (2) has been employed in the metallurgical laboratory of Globe Steel Tubes, Milwaukee, since his graduation from Purdue University last June.

Robert J. Morris (3), who graduated from Missouri School of Mines and Metallurgy in June, has been employed as a metallurgist for the Allison Division, General Motors Corp., and is working in the materials laboratory, Indianapolis, Ind.

Donald F. C. Cole (2) has joined the staff of Metals and Alloys Ltd., Montreal, Quebec, as sales manager for Quebec and Eastern Canada.

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couples. Minute changes can be measured with extreme

Speed—with electric tachometers. Change of speed can be measured over a narrow band in detailed studies of motors, engine governors, etc. Voltage—from other transducers and amplifiers,



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| Tap Life   | 2 hours                     | 8 hours                    |
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You just cannot ignore the fact that the cutting fluid used is a major factor in any machining operation. A Stuart Representative is prepared to show you how Stuart combines theory and practice to give you better operating performance. Ask to have him call.



### Personals

Paul A. Beck \$\mathrmax\$ has accepted a research professorship in metallurgical engineering at the University of Illinois, Urbana, Ill.

Truman J. Hammel (3) has recently joined the sales division of Chain Belt Co., Kansas City, as district sales engineer. He has been with the company, in the research engineering division, since 1946.

Carl A. Liedholm is now in Sandviken, Sweden, where he is starting an extensive study of hollow rock-drill steel for Sandvik Steel Works. He writes: "Understandably enough, steel airplane propellers — my wartime preoccupation with Curtiss-Wright — and hollow drill rods have much in common, and least in their ability to withstand fatigue."

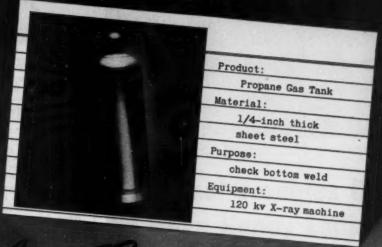
George V. Luerssen (3), formerly chief metallurgist, has been appointed vice-president in charge of metallurgy by the board of directors of the Carpenter Steel Co., Reading, Pa. Carl B. Post (3) succeeds Mr. Luerssen as chief metallurgist, and George E. Brumbach (4) has been advanced to the position of metallurgist to succeed Mr. Post.

T. W. Merrill has been appointed chief metallurgical engineer of the Vanadium Corp. of America and has been transferred from the company's plant at Bridgeville, Pa., to the executive offices in New York.

W. G. Dahl has been appointed district manager of the Hartford, Conn., area by the Latrobe Electric Steel Co. He replaces H. C. Cole have who has resigned from the company.

L. P. Josephs , owner of Pearson Industrial Steel Treating Co., Chicago, announces the following changes: Victor Bozick a has been promoted from plant superintendent to works manager; Carlton M. Fallert , formerly with Lindberg Steel Treating Co., has charge of purchasing and quality control; Alfred Francis , previously with the West Pullman Works of International Harvester Co., has been appointed metallurgical engineer in the sales department; Raymond Ericksen . who was formerly associated with the National Malleable and Steel Castings Co., has been engaged as plant metallurgist and superintendent.

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Type A has enough speed to keep exposures reasonably short even at low voltages. Its high contrast and fine graininess are also valuable in taking full advantage of higher kilovoltage machines in detecting irregularities in thick or dense materials.



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To provide the recording medium best suited to any combination of radiographic factors, Kodak produces four types of industrial x-ray film. These provide the means to check welds efficiently and thus extend the use of the welding process.

Type A-has high contrast with time-saving speed for study of light alloys at low voltage and for examining heavy parts at 1,000 kv. Used direct or with lead-foil screens.

Type M-provides maximum radiographic sensitivity, under direct exposure or with lead-foil screens. It has extrafine grain and, though speed is less than in Type A, it is adequate for light alloys at average kilovoltage and for much million-volt work.

Type !- provides the highest available speed and contrast when exposed with calcium tungstate intensifying screens. Has wide latitude with either x-rays or gamma rays, exposed directly or with lead screens.

Type K-has medium contrast with high speed. Designed for gamma ray and x-ray work where highest possible speed is needed at available kilovoltage without use of calcium tungstate screens.

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### Low Temperature Properties of Iron and Steel\*

APPLICATIONS for ferrous materials at low temperatures have increased until they now embrace certain areas in most basic industries as well as many types of military, marine and civilian needs. Conditions vary widely as to temperature, the type of service, and the character and design features of a part. The properties required of the metal in service, to insure that it will function with a high degree of safety at service temperatures, will also vary widely, though the exact requirements are apt to be difficult to specify.

It should not be construed that the use of ferrous materials at low temperatures introduces major problems of selection in every case. When, for example, materials must withstand static loads only, there may be no necessity to employ a material other than that which is satisfactory in the same application at normal temperatures. The lower temperatures strengthen and harden ferrous materials slightly so that for construction involving static loading only, it is possible that they are as good at low as at normal temperatures. As the severity of service increases, however, and materials are called upon to withstand the possibilities of shock loadings and local deformation without failure at low temperatures, increasing care must then be exercised in selection.

The conventional engineering tests on ferrous materials have provided information to show that, as the temperature of testing is decreased below atmospheric, the hardness, yield strength, fatigue strength and tensile strength increase, except for highly embrittled materials. This is not so, however, for ductility, manifested by the degree of permanent deformation before fracture by stress in tension, and for toughness, manifested by the amount of energy absorbed before fracture. With respect to these two properties, ferrous materials fall into one of two groups; namely, those which remain ductile at low temperatures and those which become embrittled.

It is characteristic of the bodycentered-cubic ferritic materials to (Continued on p. 100)

\*Abstract from "Low Temperature Properties of Ferrous Materials", compiled by the S.A.E. Iron and Steel Technical Committee, Society of Automotive Engineers, Inc.

## Tool Steel Topics



#### High-Speed Tools at Lower Cost with Tungsten-Saving 66HS

Bethlehem 66HS performed so well during the alloy shortages of World War II that many users of high-speed steels never did go back to the large-scale use of 18 pct tungsten grades.

66HS has a balanced content of tungsten and molybdenum; and it has proved ideal

for a wide variety of cutting tools. Because of its lower cost and many uses it

is much more than just an able substitute for the high-tungsten steels.

In Bethlehem's own machine shops, for example, 66HS has been used since 1942 for more than 90 pet of all our high-speed tools. We use many tons of it each year; and our production men report that year after year this grade performs just as well or better than Special HS, our 18-4-1 type of steel.

There's an economy angle to 66HS that shouldn't be overlooked, especially by

large users. 66HS at present prices costs
about \$700 a ton less than
standard 18-41 grades. And
it's 6 art lighter too.

it's 6 pet lighter, too.
66HS is hardened at 100 degrees below the hardening
temperature for high-tungsten
grades. It requires careful
heat-treating, but it presents
no problem at all to any heattune has secured temperature in.

treater who has accurate temperature indicators. This equipment is necessary because 66HS does not form beads of "sweat" on the surface when the proper hardening temperature is reached (2250 to 2275 F).

66HS has just the right degree of wear-resistance, toughness, and red-hardness for use nearly everywhere as a de-

pendable, general-purpose cutting steel.

Its typical analysis:

Like to know more about it? Ask for our Booklet 264, describing 66HS and other Bethlehem high-speed steels.



This 1%-in, diameter gage, made from ail-hardening tool steel, cracked because it wasn't tempered immediately after the quench. Tempering relieves stresses set up in the steel during hardening.

### Tool Steel Troubles Usually Have Happy Endings



Based on the many thousands of investigations they've made, our metallurgists and research men say that probably less than 3 pet of tool

failures can in any way be blamed on the tool steel.

Tool failures are usually cured by one or more of these remedies:

- 1. Improving the tool design
- 2. Using a more suitable tool steel
- 3. Correcting the heat-treatment
- 4. Improving tool-grinding technique

Some people who think they don't have

tool problems quite often aren't getting best results. For example, a plant may suddenly have a series of broken tools or dies. We're called in to help put a finger on the cause. And quite likely we'll find they have been overlooking some vital factor in tool design or heat-treatment. Correcting the trouble leads to tool performance that's far beyond the best previous service life. That's why most tool steel troubles have a happy ending.

If you have a problem involving tool steel or feel you should be getting better tool performance, let us hear from you. Maybe we can give you the right answer pronto. Or a Bethlehem metallurgist may have to work with you in your shop. In either case, there's no obligation.



### Our Tool Steel Engineer Says: Making shock tools too hard causes premature failure

Most shock-resisting tool steels give best service when hardened between Rockwell C-55 and 60—averaging about C-58. This hardness range provides the best compromise between toughness and wear-resistance. Premature failure is often the result of obtaining an excessively high hardness in these grades. Carbon tool steels are often best for shock tools re-

quiring a hardness above Rockwell C-59.

The chrome-tungsten grades of shockresisting tool steel can be carburized to obtain greater wear-resistance. This treatment produces a thin, hard case on the tool surfaces, yet retains a tough core of lower hardness. This method is often used for master hobs, reamers, swaging dies, and various kinds of shock tools.

Bethlehem



**Tool Steel** 



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Manufacturers of Metallurgical, Agricultural and Pharmacoutical Chambrals

#### Low Temperature Properties

(Continued from p. 98) show brittle behavior at some low temperature, the materials differing among themselves only in the temperature at which ductility vanishes in a specific test. On the other hand, the austenitic-type materials of face-centered-cubic structure tend to remain ductile over most ranges of low temperatures that have been investigated. They seem to become sensitive to embrittlement only when they contain sigma phase, are made subject to precipitation hardening, or are structurally unstable at low temperature.

The fracture behavior of ferritic materials is known to change profoundly with lowering temperature, the change often being characterized by a sudden loss in toughness or ductility. The temperature of change from ductile to brittle behavior is frequently referred to as the transition temperature though this temperature need not be and usually is not the same when determined by different test procedures. Variations in conditions of determination of ductility or toughness affect the transition temperature; it is dependent upon factors relating to both external and internal conditions imposed on or existing within the material when subject to fracture. Different methods of testing, with few exceptions, will place several steels in the same order with regard to their transition temperatures. A necessary consideration then, in evaluating a testing procedure, is its sensitivity in differentiation between two steels of like properties.

In service, the size and geometry of the part, the presence of surface blemishes, scratches, and deep notches, and the simultaneous action of (a) a high rate of straining, (b) a nonuniform stress distribution, (c) a multiaxial state of stress, and (d) a low temperature. are some external conditions which affect the embrittlement. Although these are extremely important, other factors related to the internal state of the metal are likewise important to the problem of brittle behavior. Among the latter are chemical inhomogeneities, internal discontinuities and cracks, grain size variations, grain orientation, residual stress, strain hardening or cold working, strain aging effects and state of deoxidation.

The general effects of low tem-(Continued on p. 102)

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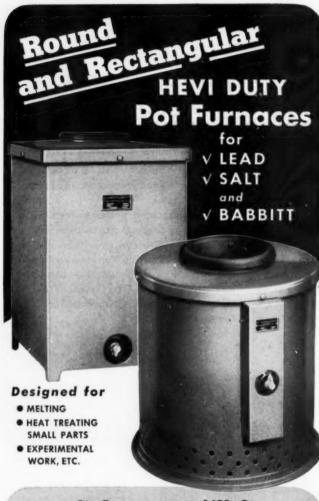
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#### Low Temperature Properties

(Begins on p. 98)

peratures on mechanical properties of ferrous materials might then be summed up by stating that, for the most part, properties are improved with decreasing temperature, and it is only the ferritic materials as a class that become embrittled at some temperature. The temperature where transition from ductile to brittle fracture occurs varies considerably, depending on the nature of the test and on both external and internal factors existing prior to and during fracture.

Some progress has been made in correlating results of conventional tests with service performance of materials at low temperatures, but designers are cautioned to use extreme care in interpreting such results in terms of material performance. All conventional tests for embrittlement provide arbitrary measures of the ability of material to resist fracture under conditions of restriction on deformation. None seem capable of integrating all the variables significant to the problem of embrittlement. For that reason, reliance can be placed on only those tests which more nearly simulate conditions in service or, at least, which have been shown by experience to give satisfactory indications of the behavior of material in its particular reduced temperature environment.

The function of the notch in the notched-bar specimen is to accentuate the effective strain rate and to provide the degree of constraint necessary to differentiate, at room or at moderately reduced temperatures and at moderately low rates of loading, between materials that will be ductile and those that will be brittle when subjected to service at either very low temperatures or under conditions of extreme shock loading or both. The V-notch specimen, because of the relative severity of the notch, is preferred for measuring the impact resistance of quenched and tempered steels of moderate to high strength levels intended for fairly severe service applications involving low temperatures and shock loading. Because of the severity of the notch, the V-notch specimen provides a sharper distinction between the applicability of steels to low temperature conditions.

The effect of velocity is important in impact testing. Increasing (Continued on p. 104)



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#### Low Temperature **Properties**

(Begins on p. 98)

the velocity increases the severity of the test and tends to promote increasingly brittle behavior. Until the effect of striking velocity is fully understood and standardized, the striking velocity should be recorded with all data.

Composition - Increasing the carbon content of a steel causes a rapid decrease in room temperature notched-bar impact results and tends to increase the temperature of transition or embrittlement. The resistance to embrittlement at low temperature does not depend so much on the quantity of carbon present as on the degree of dispersion. A fine spheroidal dispersion of iron carbide is least detrimental to low-temperature properties. A contributing factor to low impact values for high-carbon steels may be the tendency of the higher carbon steels to exhibit quench cracking under some conditions.

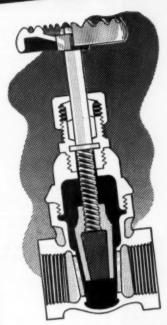
Manganese content up to about 1.5% has a beneficial influence on the low-temperature embrittlement of low-carbon steel, but larger quantities are detrimental. In steels which are sensitive to temper embrittlement, manganese has a detrimental effect on low-temperature embrittlement. An increase in the silicon content of carbon and medium alloy steels considerably reduces their notched-bar impact resistance. This effect has been demonstrated in carbon and alloy steels over the entire range of microstructure from martensite to pearlite. It is advisable to keep sulphur and phosphorus as low as possible in those steels intended for lowtemperature service.

The ideal structure to obtain a minimum transition temperature at a given hardness for ferritic steels is tempered martensite. Slack quenching, such as occurs in the interior of a large quenched section of a steel of insufficient hardenability, will produce mixed structures or structures which are not the equivalent of martensite in lowtemperature behavior. The primary reason for adding alloying elements is to increase hardenability and in this way to aid throughout in developing the desirable martensitic structures.

The effect of chromium in promoting hardenability aids in developing full hardening in the steel which on tempering produces the

(Continued on p. 106)

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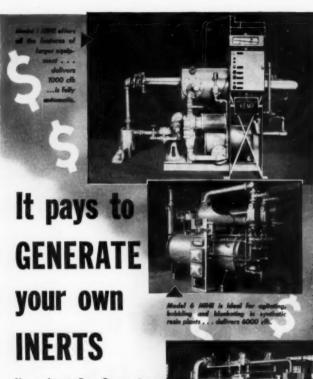


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#### Low Temperature Properties

(Begins on p. 98)

spheroidal carbide structures so desirable for low-temperature impact resistance. When used alone, chromium may have a tendency to promote embrittlement if the steels are tempered in the normal ranges. Molybdenum, as a carbide former and hardenability promoter, performs one of its chief functions by producing desirable microstructures in quenched and tempered parts. A recognized use for molybdenum in alloy steels is its property of inhibiting the temper embrittlement of susceptible steels. Molybdenum up to 0.5% is used to minimize this phenomenon.

Nickel as an alloying element in ferrous base materials is regarded as beneficial in preserving toughness at subnormal temperatures. noncarbide-forming element which is soluble in ferrite, nickel is not dependent on carbon for its major alloving effect and, therefore, it may be employed effectively in low-carbon iron and steel. A low carbon content also is very desirable in promoting low-temperature toughness, particularly in structures of a type or size where normalizing and tempering are the most drastic treatments possible. The quenched and tempered state is the most desirable.

No conclusive data are available regarding the effect of copper on low-temperature properties of steel. What is known indicates that copper in solution is mildly beneficial; in the age hardened or precipitated state it has an adverse effect on low-temperature ductility. Data available are not extensive enough to draw conclusions regarding the effect of vanadium, columbium, aluminum, titanium and zirconium.

Vanadium increases hardenability whereas aluminum, titanium and columbium decrease it. In general, they raise the grain coarsening temperature. Their ability to fix oxygen, nitrogen and sulphur and to promote fine grain size is beneficial to low-temperature notch impact. There are optimum additions of these elements above which no further benefit may be derived or detrimental results accrue. No data are available relative to the direct effect of tungsten.

Nitrogen has been shown to give rise to precipitation or aging effects when present in amounts ordinarily found in low-carbon iron and steel.

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#### Low Temperature Properties

(Begins on p. 98)

The effect of increasing nitrogen content is to decrease the impact resistance and raise the transition temperature. Although there are indications that oxygen itself does not cause aging, it seems to have a secondary influence on the amount of nitrogen or carbon required to cause aging. The embrittling effect of oxygen in steel and iron is modified perceptibly by the presence of strong deoxidizers. The effect of hydrogen on the embrittlement of steel and iron at low temperatures appears not to have been determined as yet.

Influence of Steel Making - Optimum properties for a wrought steel of given composition and structure are obtained when it is fully killed with aluminum in sufficient quantities so that a definite amount is retained in solid solution (between 0.02 and 0.08% Al). This treatment lowers the oxygen content of the steel and produces a fine-grained material. The bulk of the evidence seems to indicate that carefully controlled deoxidation with aluminum should improve the low-temperature properties of cast steels. The part played by grain size is not so clearly brought out as in the case of wrought steels. However, the fine-grained material performs the best. Normalizing or heat treatment will give higher values for impact.

Influence of Microstructure -Although the effect of mixed structures, resulting from heat treatments other than full quenching. still remains to be determined quantitatively, the studies reported in the paper by Stout and McGeady, The Welding Journal, 1947, p. 683-S to 692-S, show the importance of metallurgical structures. Grain size exerts a marked influence upon the toughness of steel at reduced temperature. For any given strength level, fine-grained steels generally possess significantly higher notchedbar impact values than coarsegrained steels, and also retain their toughness down to lower testing temperatures.

Temper embrittled fine-grained steel possesses approximately the same toughness at all testing temperatures as the same steel in the unembrittled but coarse-grained condition. The specific effect of small additions of various alloying elements in increasing the low-

(Continued on p. 110) -



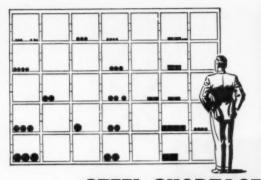
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#### Low Temperature Properties

(Begins on p. 98)

temperature toughness of steel may not be due to the alloying effects of the added elements but traceable to their influence upon the grain size.

Enough evidence is now available to indicate that constituents, whether ductile or brittle, in continuous or network arrangement in metal are harmful. Treatments which tend to destroy the network envelopes or make the constituents less continuous in form will provide some improvements in toughness, ductility and notch-resistivity at low temperatures.

Banding and laminations are undesirable. Inclusions are detrimental also but vary in degree according to their form and distribution. Small, hard, angular particles are the least desirable type.

(A concise discussion on heat treating, tempering, temper embrittlement, and quench and strain aging is included. Of particular interest here is the quench from tempering temperature to avoid temper embrittling effects. It is possible to minimize the effects of temper brittleness by selecting an alloy composition which has a high resistance to softening so that a tempering temperature in excess of 1100° F. will be required to produce the desired hardness. It will then be possible to water-quench after tempering and avoid embrittlement. When the tempering temperature must be below 1100° F., the highest temperature and shortest time practicable should be employed, followed by a water quench after tempering.)

Effect of Welding — All factors which affect the notch toughness of steel affect the notch toughness of weld metal. The welding process has little effect on an unnotched tensile specimen in terms of yield point, ultimate strength, reduction in area, and per cent elongation. The evidence, however, points to the fact that welding has an adverse effect on the notch toughness of steel. This detrimental effect of welding on notched specimens has been confirmed by a variety of tests.

Welded structures which are well designed and constructed with consequent elimination of any type of notch effect will perform extremely well.

The performance and strength of a welded structure are influenced by the use of different types of (Continued on p. 112)

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#### Low Temperature **Properties**

(Begins on p. 98) electrodes, preheating, postheating and special welding procedures. This is confirmed by work of Grossman and Shepler who determined the transition temperatures to brittle fracture of various types of electrodes and welding methods. It is immediately evident from their graphs that the lime-coated ferritic electrodes (A.W.S. 6015) and the process of automatic welding gave very low transition temperatures in the weld metal as compared to the unaffected base plate. The highest transition temperature is encountered about 1 in. from the center of the weld. The use of E6020 electrodes shows better results than E6010. The latter shows its worst effect at the fusion zone, while the E6020 electrode reaches the highest transition temperature well in the heat-affected zone. The oxyacetylene welding process has been found to offer the poorest results. the zone most affected being the center of the weld.

Influence of Design - There is no fundamental difference in the influence of the various design factors upon the behavior of steel parts at reduced temperatures as compared to room temperature. There is, however, a difference in magnitude of the effects of design upon the performance of steel structures at reduced temperatures. Stress concentrations and triaxial stress patterns should be designed out of a structure to be subjected to low-temperature service.

Wherever possible, thin sections should be utilized in the design because: (a) the increased constraint upon local deformation impaired by the surrounding mass of rigid metal promotes the brittle type of fracture; (b) it is more difficult to obtain the tough, tempered martensite microstructure in heavy sections; (c) with the higher alloy needed to get full hardening in heavier sections, the metallurgical difficulties of temper embrittlement and quench cracking are more prevalent.

Steel parts subjected to fatigue at low temperatures have an increased resistance to crack initiation; but, once the crack is initiated, it will propagate to complete failure at a much more rapid rate than at normal temperatures. Therefore, care must be taken to avoid high stress concentrations.

(Continued on p. 114)

**METAL PROGRESS; PAGE 112** 

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METAL PROGRESS; PAGE 112-B

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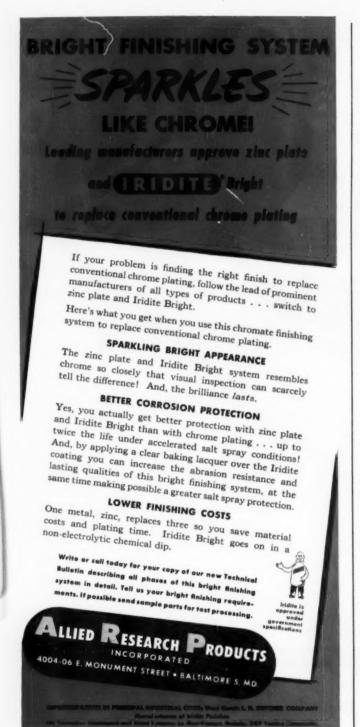
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#### Low Temperature Properties

(Begins on p. 98)

Surface Condition and Finish—Surface hardening treatments result in a part with a hard surface layer having a residual stress pattern varying according to the treatment and depth of case; consequently, this layer is very notch-sensitive. It is thus even more important that such parts be free of any notch effect. Steels and thermal treatments should be so specified that the core material will have an adequate degree of toughness. Thus, carburized steel parts are not recommended.

Surface imperfections such as scratches, machine tool marks, stamped-in numbers, and other flaws may be focal points of failure of severely stressed parts.

Steels for Low Temperatures — It is apparent that no set rule exists to govern the selection of a steel for a particular low-temperature application. In the design of components, the variables must be considered separately on the basis of the following factors: Type and distribution of stress, rate of strain, specific temperature range involved. In general, the more severe these conditions are, the lower must be the transition temperature of the steel in the Charpy test.

The ideal microstructure to obtain a minimum transition temperature in ferritic steel is tempered martensite. Hardenability is, therefore, an important factor. In addition, deoxidation, grain size, and susceptibility to temper brittleness must be considered.

It is not feasible here to repeat the long discussion on the selection of steels for service under increasingly low temperature, or to condense it. It is sufficient to state that suitable steels are available for service under all conditions of temperature, running from plain carbon through to the austenitic types as conditions become increasingly severe. The steel's alloy content alone is no criterion of its behavior because heat treatment. melting and deoxidation practice, grain size, tempering treatment, design, and other factors all play their roles. At very low temperatures, great care must be taken in the application of welding and other types of postheat treatments.

Specification Limits — It would be unwise to attempt to specify any given test or a range of test values to be used to control quality of

(Continued on p. 116)



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Holcroft furnace for carbo-nitriding bulk-loaded automotive parts. Has automatic guench and draw.

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CARBO-NITRIDING provides a "gas cyanided" case by heating the work in a controlled atmosphere composed of generator gas, hydrocarbon gas and ammonia. This Holcroft process uses continuous-type furnaces such as the unit shown above, and offers these advantages:

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- 4 Minimum distortion through low-temperature operation and slow cooling when required.
- 5 Applicable to both plain carbon and alloy steels.

Although the theory behind carbo nitriding is mentioned in a patent issued in 1883, it was not applied to high-production furnaces until rediscovered independently by Holcroft & Company in 1936. The first furnaces of this type, built 15 years ago, are still in operation; many other production furnaces installed since then have further proven the merits of this process.

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#### Low Temperature Properties

(Begins on p. 98)
materials for use at low temperatures under all service conditions.
Therefore, it is suggested that a material and test to control the desired properties be selected for a given operation. After material and test have been selected, then test values should be established through actual test at the lowest temperature at which the material is to be used in service.

The range of specification limits should be established only after careful correlation with service performance. Caution should be taken to avoid establishing requirements on limited data, since it is possible to have service temperatures which fall in the transition zone for the material being used, and results could be obtained which could not be readily reproduced.

H. J. NICHOLS and S. A. AGNEW

#### Centrifugal Castings for Aircraft Engines\*

H IGH-ALLOY steel components for aircraft engines, which are generally cylindrical or disk-shaped, are reliably and economically produced by centrifugal casting. Firth-Vickers Stainless Steels, Ltd., Sheffield, England, has produced more than 1% million parts by its "Centrispinning" process, first for sleeve-valve piston engines, later for turbojet and gas-turbine engines.

The centrifugal method used is dependent on the shape and design of the component. Generally, if the length of the part is greater than the radial thickness, spinning about the horizontal axis is generally preferred, but if the radial thickness exceeds the length, the vertical method is often used. The cast component rotates about a true axis in either method during pouring and solidification. No cores are required where the internal shape is regularly cylindrical. Metal molds are preferred where their use is possible because directional solidification is assisted by the chilling action of the mold and finer grain is produced in the austenitic alloys.

(Continued on p. 118)

\*Abstract of "Centrispun High-Alloy Steel Aero-Engine Components", by A. E. Thornton and J. I. Morley, Symposium on High-Temperature Steels and Alloys for Gas Turbines, Iron and Steel Institute, February 1951, p. 189-194.



#### ACID ADDITION AGENT

Stops fuming of acids — promotes better wetting — lowers drag-out — saves acid — less harm to operator — less corrosion on surrounding equipment — more uniform pickling effective with sulphuric acid hot and cold — hydrochloric — phosphoric — hydrofluoric acids.

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A new complete inhibitor to stop attack on base steel — high inhibition in sulphuric—hydrochloric—phosphoric acids—lowers surface tension—less drag-out—saves acid—reduces rusting after pickling—reduces fuming—bright pickling—makes pickling a more pleasant and healthful operation.

#### COMPOUND NR-37

Prevents rusting during drying but leaves no residue — added to hot or cold water it permits drying without rusting and leaves steel clean for painting — very effective for porous castings.

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TiCu — A master alloy easily introduced by normal foundry practices. Assures high yield at comparatively low cost.

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#### ... and MH Zirconium is available as -

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METAL HYDRIDES INC. 12-24 Congress Street BEVERLY, MASS.

#### Centrifugal Castings for Aircraft Engines

(Continued from p. 116)

Where an irregularly shaped part requires a refractory mold and refractory core the process is termed "semi-centrispinning" and the axis of rotation is usually vertical. With refractory molds there is always some tendency for erosion of the mold surface with consequent danger of entrapping nonmetallies in the casting. The castings produced in "permanent" metal molds therefore are generally cleaner of harmful inclusions.

To insure freedom from shrinkage porosity, due consideration must be given, as in static casting, to achieving directional solidification and to providing adequate metal for feeding. This is more easily accomplished in the centrifugal process where the first metal poured goes to the outer periphery and freezes first, and the last metal poured is nearest the center to feed outwardly into the solidifying part. To consistently achieve this desirable state of affairs, it is necessary in many cases to add feeding metal. This can be subsequently removed by machining. Much depends upon the correct control of speed of rotation, rate of pouring, and casting temperature.

The advantages of centrifugal casting methods are summarized as follows: Highest quality of metal and freedom from defects or porosity; freedom from directional or center-line weakness; flexibility in production; and ability to process alloy compositions which are difficult to form by usual methods.

Quality control and inspection must be of the highest efficiency to insure that the quality of the outgoing product is consistent with the best possibilities of the centrifugal process. The detection of defects is somewhat simplified by the fact that in centrifugal castings the flaws are nearly always surface defects either on the periphery or in the core. Rough machining and then hot pickling or macro-etching is the most efficient method for inspecting austenitic steel parts.

Three steels which have been produced most extensively for turbojet and gas turbine applications are an 18-8 chromium-nickel stabilized with titanium, 18-12 chromium-nickel stabilized with columbium, and a 24-12 type with nearly 3% tungsten. The columbium-stabilized

(Continued on p. 122)

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The design and construction of this Rolock engineered-to-the-job furnace basket is a practical example of heat and quench efficiency.

Vital seconds are saved thru operation of the twopiece center drop-bottom grid which dumps a dense load more uniformly than the usual one-piece grid with single hinge. It is foolproof...instant... rugged. The work hits the quench at practically its maximum temperature for uniform, high quality pit type furnace heat treating. Fabricated-welded construction and the use of a high nickel alloy insure long service life, thus conserving scarce

Basket weight is 157 lbs.; load 1200 lbs.; a favorable high ratio of almost 8 to 1.

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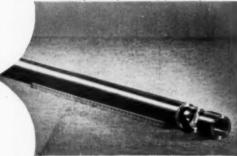
## portrait!

#### METAL MOLD CENTRIFUGAL CASTING SPELLS ECONOMY AND EFFICIENCY

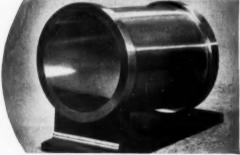
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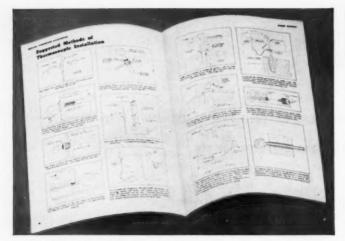
Wall Thickness - 1/8" and up

Length - Up to 14' in the "as-cast" condition

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#### CHECK THESE ADVANTAGES FOR YOUR CYLINDRICALLY-SHAPED PRODUCTS:

- Reduced Processing Time and Increased Production.
- Minimum Scrap Loss.
- Design of parts to suit the specific job requirement by selecting the correct alloy — not the next best available alternate.
- Conservation of critical metals and alloys –
  especially on tubular parts now produced from
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You save, second, by having adequate reserves always on hand, thus avoiding delivery delays which might be costly.

Bristol carries stock for immediate shipment in Waterbury, Conn., Chicago and San Francisco.



#### Centrifugal Castings for Aircraft Engines

(Continued from p. 118) alloy with 12% nickel has the best creep properties but is not easy to cast and is sensitive to hot tearing. The higher chromium alloy with tungsten has the best scaling resistance and good casting properties. The titanium-stabilized alloy has good ductility and adequate stability but may have titanium-rich inclusions to which some engineers object.

It is apparent from this paper that the centrifugal casting practices in England embody no new principles not already well proved in this country. The control and inspection practices to insure optimum quality have apparently been developed to a very high degree. C. K. DONOHO

#### High-Tensile Structural Steel\*

Strength of steel may be hanced by (a) cold work, (b) TRENGTH of steel may be enheat treatment or (c) the addition of alloying elements. For structural purposes, where steel is used in asrolled condition, only the third method has widespread application. The main requirements for a good structural high-tensile steel are sufficient strength to permit saving in weight commensurate with added cost, good plastic range to reduce the adverse effects of stress raisers such as notches, good ductility and impact strength, high fatigue resistance, ease of fabrication, weldability and improved corrosion resistance.

Weldability of high-tensile lowalloy steels has been improved by limiting the carbon content and introducing special alloying elements, such as titanium, molybdenum and vanadium. Considerable effort also has been directed toward better welding technique, including the use of special electrodes, most favorable gage of electrodes and optimum welding speeds. From the corrosion point of view, coppernickel-chromium compositions show to advantage but the carbon-siliconmanganese group has no particular

While the usual high-tensile steel in British use has a yield stress 50% (Continued on p. 124)

\*Abstract of "Structural High-Tensile (Low-Alloy) Steel", by O. A. Kerensky, Engineer, March 1949, p. 238-241.

## **HEAT TREATING FURNACES**

For ALUMINUM

Aging • Pre-heating Solution heat treating

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Stress relieving • Normalizing Aging • Tempering • Drawing

For all heating requirements up to 1350° F. where accurate heat control and uniformity in the work chamber is desired. Car bottom furnaces. Bottom entry quick quench furnace for solution heat treatment of aluminum. Conveyorized furnaces and all other material handling designs.



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Brandt's proximity to steel mills and rail and water transportation assures you on-time delivery.

\*Regardless of stepped-up defense production, our industrial accounts still receive prime consideration.



#### High-Tensile Structural Steel

(Continued from p. 122) higher than that of mild steel, the practice of bridge engineers has been conservative and the allowable working stresses have been increased only 40% in general. Apparently, this conservative position has been taken because of the limited experience with the newer steels.

The selection of suitable steel for a structure is governed by technical considerations, such as where lightness is obtained with use of superior steel as in bridges for military use, or where corrosion resistance must be obtained; or by commercial factors where the use of superior steel results in a structure of lower cost. The first cost of steelwork in a structure is made up of seven main items: Costs of (a) plain material (high-tensile structural steel requires the addition of alloving elements involving addition costs, not only in the supply of the alloys, but also in the increased difficulties in production), (b) fabrication, (c) transport, (d) erection, (e) painting, (f) overhead, and (g) profit. The author analyzes the situation for an average structure in Great Britain and shows that, if the percentage weight saving resulting from the use of high-tensile steel is P, the saving is cost of steelwork is approximately ( $\frac{1}{2}P-3$ ). The weight saving anticipated by the use of high-tensile steel in various girders and joists is computed and ranges from 6 to 27%, depending upon section, span and loading.

There are general advantages to the industrial economy resulting from the use of high-tensile steels so that their more extended use in structures seems justified even though the monetary saving in the individual case may not be large.

S. FEIGENBAUM

#### Gas-Turbine Materials\*

THE SPECIAL material problems of large closed-cycle gas turbines, as distinguished from open-cycle plants, center on the air heater, where long life is required of tubes working at temperatures up to (Continued on p. 126)

\*Abstract of "Gas-Turbine Performance and Materials", by J. B. Bucher, Symposium on High-Temperature Steels and Alloys for Gas Turbines, Iron and Steel Institute, February 1951, p. 17-23.



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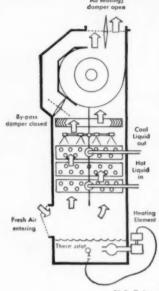
c/<sub>O</sub> American Society for Metals 7301 Euclid Ave., Cleveland 3, Ohio Telephone—UTah 1-0200 NATIONAL METAL EXPOSITION

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- Extends quenching capacity without extra water or cooling tower.
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#### APPLICATIONS

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Cooling water and
brine
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compressed air

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#### Gas-Turbine Materials

(Continued from p. 124)

1500° F, with maximum operating stresses of the order of 3500 psi. It is unsatisfactory to extrapolate creep and rupture data from tests of only about 5000 hr. duration to time periods of 190,000 hr., and the author makes a plea for a few check points at 20,000 to 50,000 hr.

Another problem unique with the closed cycle is that the tubes are cold worked in manufacture, and for most materials it has not been determined how this affects the creep and rupture life or what heat treatments may be required subsequent to cold working to restore the inherent strength of the alloy. If a solution treating temperature of the order of 2300° F. is required, this probably would be found impractical due to the long lengths of tubes. The tubes must also be joined to one another and to the tube sheets by welding, and adequate data are not available for most materials on weldability and the high temperature strengths of

The most serious problem encountered thus far, however, is corrosion from fuel oils having high vanadium content. In closed-cycle plant tests of 200 hr. at about 1500° F. maximum tube temperature, tubes of a complex nickel-chromium-cobalt austenitic steel were completely perforated. The ash deposits contained approximately 80% vanadium as VoOs. An opencycle gas turbine experienced blading attack after firing for about 300 hr. with a fuel oil that left an ash containing 25% vanadium as V2O3. The turbine inlet temperature was about 1200° F.

The author couples these observations with numerous laboratory tests and makes the statement that no heat resisting alloy is immune to even very small amounts of vanadium. Attack seems to begin at about 1100° F. and at about 1300° F. no material can be expected to have a life of more than a few thousand hours. It has been observed that complex nickel-chromium-cobalt alloys (such as G18B or Rex 326) are more readily attacked than high nickel alloys (Nimonic 80) or the standard 18-8 columbium or titanium stabilized materials.

During one run with the closedcycle plant, carbon tetrachloride was added to the oil in an effort to volatilize the vanadium. This procedure did not produce an

(Continued on p. 128)



## Only Individual in the U.S.A. with No Interest in the Steel Situation

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You know the steel picture as well as we do.

In these rearming times, our mills are producing every ton of steel to capacity, yet we still can't fill all the requirements of our regular customers or go out looking for new business.

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WISCONSIN STEEL

SEPTEMBER 1951; PAGE 127



Any steel treating process available on a commercial basis is waiting for your order at Lakeside! Expanded facilities. new and faster equipment make the time between your "ticket", and delivery of heat treated parts exactly as specified. much shorter. Call your Lakeside metallurgist today—he has the answer to any metal treating problem.





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methods for barrel debur-

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lou'll Find IMPROVEMENTS For Wowr FINISHING OPERATIONS in this BULLETIN ...

> For example . . . pages 6 and 7 detail a new method of removing heat scale and rust-eliminating the use of hazardous liquid acids. It has the following interesting advantages:

- Safe . . . non-inflammable . . . non-explosive.
- · Economical . . . used in either hot or cold solution.
- · Eliminates danger of overpickling.
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- Saves time . . . improves finish . . . does a complete job.

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#### Gas-Turbine Materials

(Continued from p. 126) improved result, and may have accelerated the attack. Other additives have shown more promise and experiments are continuing.

The author points out that designers encounter a "no man's land" between about 1025 and 1100° F. in the selection of materials for long life. Below this range, more or less standard ferritic steels are satisfactory, and above, austenitics are required. He emphasizes the need for improved ferrities so that it won't be necessary to overdesign by using austenitics in this range.

C. T. EVANS, JR.

#### Joining Metals With Resin Adhesives\*

RONDING OF METALS with synthetic resin adhesives is compared with the older methods of fastening and while all these have their limitations, particularly in the case of heat treated aluminum alloys, synthetic resins are, in many instances, to be preferred, especially for light alloy work.

The chief recommendation for resins is that they may be easily changed from liquids, or from solids with low melting points, into hard infusible materials that are resistant to a wide variety of conditions including exposure to weathering, acids and alkalis. These phenolic resins may be prepared as viscous liquids which, with the help of suitable solvents, are brushed or sprayed on metals and then hardened by baking for a short time at 280 to 300° F. Hardening may also be made to occur without heating with the use of a suitable catalyst. Acids or acid formers may be used particularly with urea-formaldehyde resins. The use of acid formers, however, is not suitable with metal as corrosion takes place readily.

Reference is made to pressure welding to explain the formation of a satisfactory bond resulting from the forces of attraction when molecules of metal are brought into sufficiently close contact. Suitable resin adhesives, when applied to perfectly clean metal, may be looked upon as the filling-in of microscopic voids in the surface, with

(Continued on p. 130)

\*Abstract of "The Bonding of Metals", by C. J. Moss, Metallurgia, June 1951, p. 267-272.

## \* Metal Show Facts



\*NATIONAL METAL EXPOSITION

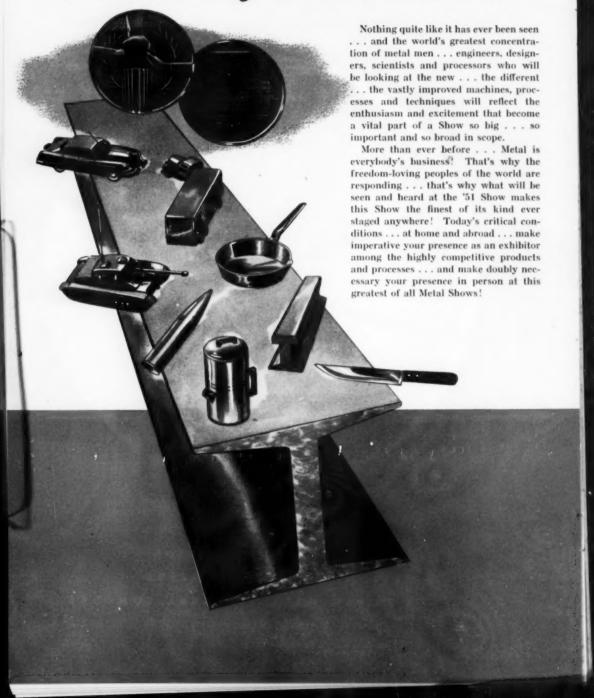
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Detroit, Mich. • Oct. 15-19



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Whenever the nation's leading metal men take time off at the peak of production to congregate in ONE PLACE and to check on what's new . . . what's faster, better . . . to look purposefully into competitive fields and to spend a full week or more absorbing the fullest information on new techniques . . . you've got BIG BUSINESS.

The 45,000-plus metal men who will attend the 1951 Metal Show will be there on business . . . YOUR BUSINESS if you are an exhibitor and if you have your Show staff primed and trained to do a top-notch selling job! With today's world conditions demanding more and more production . . . with defense orders swinging into high gear and consumer demand sure to boom again with relaxed credit controls . . . the metal men of the nation and the world will be keenly interested in anything that will facilitate their production in an era of peak demand.

What's more . . . the new techniques and the new ideas you'll hear at the technical sessions will keep you abreast of competition and informed on the important changes the metal industry faces in the years ahead. You can't afford to miss . . . with your products or services . . . or your key men!

SOLD is the word that keeps the metal industry moving . . . and that's the tag you'll see on a staggering volume of business directly started and closed at the '51 Metal Show.

Plan to follow up every sales lead that's sparked on your products or services at the Show! With more than 1,125 metal men per hour passing your exhibit . . . it'll be up to you and the stopping power of your display to get your share of the BIG BUSINESS that will be exposed to your sales efforts!



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Measuring the impact of the Show itself on the metal industry men who make it their business to attend is a complex and difficult thing... but experience has proved that fact that long months after the Show itself is history—the Show keeps right on selling for those exhibitors who had what it takes in the way of products, processes or services. What they see, what they learn and what they take away with them is the key to the business that keeps right on piling up from the metal men... even repeat business that started with a purchase during the Show.

Exhibitors have learned much from experience, too. That's why the displays being prepared now for the '51 Show are smarter, snappier than ever before . . . that's why they've added motion, color and excitement to their displays. Good showmanship is good salesmanship and your exhibit, properly and attractively designed, will get you a share of the attention and the sales that are started at the Show.

A few good spots are still available and your reservation for this greatest of all metal shows ought to be on its way this very minute to assure your chance of bigger sales where the biggest group of metal industry buyers will be . . . Detroit, Mich., Oct. 15-19. There's no time to lose!

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- They'll check on major improvements
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## The Metal Show

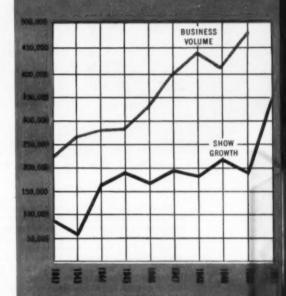
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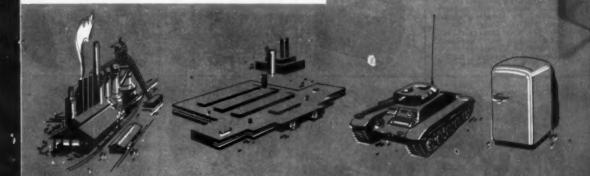
It's going to be a whale of a year . . . because it's going to be a whale of a Show. That vardstick works-and over the years when the Show has been big, bustling and packed with competitive products, it's meant a busy year for the metal industry. Right now this one figures to be the Show of Shows . . . in size, in scope, in impact on defense and civilian producers of things fashioned of metals

As a business barometer, the Shows have reflected the moods of business everywhereand this year there is every indication of booming production . . . sustained high sales and consumer markets to gladden the hearts of all alert manufacturers. Proof of that lies in the growing lists of exhibitors who want in on this greatest of metal round-ups-and the reasons expressed for demanding a spot in the "big league" Show. Those reasons vary from a sober realization that no matter what comes they'll have to fight for their markets . . . to a buoyant optimism over sustained good business.

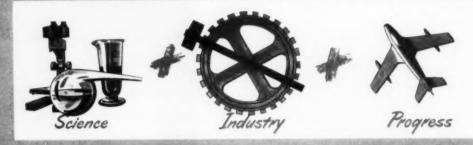
Beyond the market predictions of those exhibitors who sell to the metal industry lies the sound and proven need for retaining identity and product prestige in the Show itself. Long ago the wiser suppliers to the metal industry learned that it makes a lot of sense to be a remembered unit in the big parade of the metal industry!



The chart above shows the steady growth of the Metal Show over the post-war year and the growing demand for all thing made of metal. A sharper upturn for the early months of '52 is indicated in the upturn of exhibitors showing in the '5



# The National Metal Congress



Want to know what's cooking for the metals you work with? Want to know about newly engineered formulas for metals that'll bend, shape, form easier, faster—that'll take a better finish or perform a specific job at lower cost? Without exposing what the metal scientists have up their sleeves for this vital phase of the Detroit events, it's a good guess that every man who works with metals will find the time spent at these sessions mighty helpful and maybe profitable, too, for the immediate months ahead.

Conservation, substitution and best use of critical metal supplies are sure to get a thorough airing . . . as well as new ways of making metals behave under today's special needs. Plan your Show time to include the sessions of the Metal Congress and be sure your engineers and your key men are present to keep abreast of what's new and important in the frontier of metal development. Check your programs and make sure you don't miss the exciting, informative, educational hours planned for you!

The Metal Congress, as in years past, will feature the technical progress of the following national technical societies: American Society for Metals; American Welding Society; Society for Non-Destructive Testing and the American Institute of Mining and Metallurgical Engineers, Institute of Metals Division.















# ... The World Metallurgical Congress

Freedom Understanding Common Defense

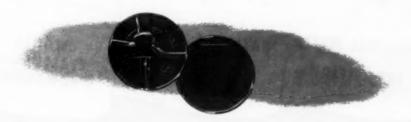
# ... the first event of its kind in all History

It has taken man endless centuries to reach the point where, for a common defense against a common enemy, he is willing to share with his neighbor the knowledge he has accumulated in the making and the development of weapons for defense.

Now, for the first time in history, under the sole sponsorship of the American Society for Metals, free men from the free nations of the world will pool their resources . . . in arms, in manpower, in SCIENCE. What concerns the metal industry of America rests in the knowledge, the techniques and the conservation experiences that will be brought forth at the World Metallurgical Congress.

Because hundreds of foreign metal scientists will be present and because a natural reticence might make them a bit shy of open discussion with American metal industry men—it'll take a lot of that easy, solid good fellowship Americans have to make our guest scientists feel at ease . . . to feel at home. From these men Americans should learn much of production in times of critical shortages . . . for these men have worked and produced under severe handicaps and what they have accomplished should add measurably to our stock of knowledge.

Facing a common enemy, the most precious weapon at our command is KNOWLEDGE . . . and to anyone who can help, by his experience and his scientist's hunger for accurate information—America should and will extend the courtesy of deep interest and encouraging response. So plan now to be there . . . plan to learn all you can from the scientists who have never had the advantages Americans consider routine in the development and production of weapons for defense!



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WORLD METALLURGICAL CONGRESS

# How to select grain structures for better machinability of alloy steels



Blocky Ferrite, Low (



Spheroidized, Med. C.



Lamellar, Med. C

The combination of grain structure, ductility and hardness has, in general, much to do with the degree of machinability of an allow steel.

For purposes of comparing different types of machinability, all alloy steels may be grouped in three carbon ranges: low carbon, .08 to .30 pct; medium carbon, .30 to .50 pct; and high carbon of .50 to .80 pct.

Each of these ranges must be considered separately, as each has a pronounced effect on the corresponding grain structure and machining properties. Certain grain structures may be well suited for one type of machining and at the same time wholly unsuited for others. For example, in a medium carbon range, an alloy steel with a spheroidized structure may be good for turning operations, poor for forming, fair for drilling, and poor for broaching. This, of course, means that a compromise must usually be accepted to get the most economical overall machinability in any one grade of steel.

The table shown here is a suggested guide. It contains various combinations of carbon range, heat-treating process and structure believed to be most suitable for each type of machining.

Our metallurgists will gladly furnish further information on the relative machinability of various alloy grades. Call or write for this information.

Bethlehem is a dependable source for all of the AISI alloy steels as well as the full range of carbon grades and special steels.



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Sorbitic, Med. C



Spheroidized, High C



Lamellar, High C



Sorbitic, High C

| CARBON RANGE          | PROCESS             | STRUCTURE      | TURNING | FORMING | DRILLING | BROACHING |
|-----------------------|---------------------|----------------|---------|---------|----------|-----------|
| LOW (C .08 to .30)    | Normalize or Anneal | Blacky Ferrite | Good    | Good    | Good     | Good      |
| MEDIUM (C .30 to .50) | Anneal              | Spheroidized   | Good    | Poor    | Fair     | Poor      |
| MEDIUM (C .30 to .50) | Anneal              | Lamellar       | Fair    | Good    | Good     | Good      |
| MEDIUM (C .30 to .50) | Heat Treat          | Serbitic       | Feir    | Fair    | Fair     | Fair      |
| HIGH (C .50 to .80)   | Anneal              | Spheroidized   | Good    | Good    | Good     | Fair      |
| HIGH (C .50 to .80)   | Anneal              | Lamellar       | Fair    | Poor    | Poor     | Poor      |
| HIGH (C .50 to .80)   | Heat Treat          | Sorbitic       | Good    | Fair    | Good     | Good      |

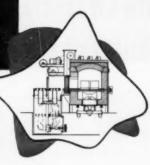
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STEELS



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# WIDER VERSATILITY

Whether it's gas cyaniding, gas carburizing, clean hardening or carbon restoration work, the Dow Furnace is capable of processing a variety of parts having a wide range of heat treatments. To demonstrate the close tolerances of heat treatments, send us samples of your own parts for processing.



# ➤AT LOWER COSTS



Reductions in direct labor, material handling, machining and cleaning costs, coupled with improved quality, have resulted in savings amortizing the original cost of the Dow Furnace in a few months. Gas cyanides for 1/4 to 1/5 the cost of liquid cyaniding.

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## Joining Metals With Resin Adhesives

(Continued from p. 128)
the result that the resin adheres to
the uneven metal surface and the
main base metal adheres to the
resin.

Phenol-formaldehyde resin may be brushed on metal and a polyvinyl formal powder sprinkled onto the resin. This powder makes the glued joints tough but it does not "wet" the metals properly, even when subjected to heat and pressure. The thin coating of phenolformaldehyde, however, wets the metal efficiently and is also a particle solvent for the polyvinyl formal. Together the two make an excellent metal adhesive. Rubber may be bonded to metal.

Glued joints are strongest in shear and are good for tension, but they should not be subjected to a "peeling" effect or the rolling back of one sheet of metal from another, which causes stress concentration in a narrow band. Resin glued joints have been made having a shear strength of 8800 psi., while a strength of 5000 psi. is obtained readily. One of the latest resin compounds, "Araldite", has given a strength of 10,000 psi.

HAROLD J. ROAST

## Increasing Bessemer Production\*

DUBING a shortage of hot metal while a blast furnace was down for rebuild, oxygen from a driox station was used in one 28-ton converter to melt as much additional scrap as possible, because any additional scrap would increase the weight of gross metallic charge and thereby increase ingot tonnage.

Under normal operations in a charge of 60,000 lb., 4000 to 5000 lb. of steel scrap can be melted by using 4000 to 6000 cu.ft. of oxygen. The blowing time is shortened about 1 min. The blast used is 25,000 to 35,000 cu.ft. per min. at 25-30 psi. More than 2900 oxygenated blows have been made in which about 6000 additional tons of scrap have been melted using about 15 million cu.ft. of oxygen. The driox plant delivers about 600,000 cu.ft. of gaseous oxygenes.

(Continued on p. 132)

\*Abstract of paper, "Oxygen as a Means of Increasing Bessemer Production", by W. G. McDonough, presented before the General Meeting of American Iron and Steel Institute, May 23-24, 1951.

# A Stainless Job That Points to Success



When your talk gets around to Stainless for your own future products, this Stainless job points the way to giving you extra advantages. It shows why it pays to consider Carpenter for Stainless that will do the unusual.

Take a second look at this job, for example. Tolerances were close, and had to be "on the nose" every time. Finishes had to be "perfect", to insure accurate operation. And like all other precision jobs, the parts had to be produced with minimum rejects.

In today's planning for the future, if you have the problem of recommending a Stainless that will give you something extra in performance or in production, it's a good idea to call Carpenter. Put Carpenter's experience with Stainless to work on your jobs.

Helping engineers get improved or

unusual results with Stainless is our favorite job. From the time the first free-machining Stainless was invented in Carpenter's laboratories, we have been developing new Stainless Steels and improving old ones. They are

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# All the facts you need in this FREE BOOKLET



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Increasing Bessemer Production

(Continued from p. 130) gen daily at a line pressure of 125 psi, of which 200,000 cu.ft, is available to the bessener department.

The first six oxygenated blows were charged with 10,000 lb. of scrap compared with 5000 lb. used in the reference blows. Beginning 30 to 60 sec. after the start of the blow, 1500 to 2000 cu.ft. of oxygen was introduced for approximately 6 min. This resulted in 24.2% oxygen in the total blast consumed during the entire blow. All of the scrap melted, but the temperature was lower than in the reference blows.

Varying the amount of oxygen with the same scrap charge indicated that some oxygen was being blown through without reacting. A standard practice was developed using 4 min. of oxygen at 1500 cu. ft. per min. starting 2 min. after start of blow. The scrap charge was 2000 lb. less than double that used in the reference blow. After a few days the scrap charge was changed to an even 4000 lb. more than that used in the reference blow. The flame and pyrometer indicated nearly the same temperature for this practice as for the reference blows. Following further experimentation, the practice adopted was to use oxygen for 4 min. at 1000 cu.ft. per min. starting after the carbon flame.

In decreasing the oxygen per blow from 15,000 cu.ft. down to 4500 cu.ft., the additional scrap melted per thousand cubic feet of oxygen increased from 400 up to 1000 lb. Almost 1000 lb. of additional scrap can be melted per 1000 cu.ft. of oxygen with an upper limit of 5000 lb. additional scrap per blow. Using more than 4000 to 6000 cu.ft. of oxygen per blow wastes oxygen and impairs quality, yields, and cost.

Use of 3000 lb. of roll scale (which contains 825 lb. of oxygen) in a 60,000-lb. charge decreases the blowing time about as much as does 12,000 cu.ft. of oxygen which weighs 1000 lb. The roll scale chills the metal so that the scrap charge must be decreased 1000 lb. for each 1000 lb. of scale used. Most efficient use of gaseous oxygen is obtained with 1000 lb. of steel scrap or equivalent steam as a coolant for each 1000 cu.ft. of oxygen to offset the excess temperature developed. These results suggest the use of roll scale (if available) where the chief

(Continued on p. 134)



The precision quality of Gordon Thermocouple Extension Lead Wire is the result of continued experience since 1915 in careful selection and inspection that meets rigid insulation requirements and Bureau of Standards specifications.

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#### THE PHYSICS OF POWDER METALLURGY

2 Here are the twenty-two papers presented at the Symposium on the Physics of Powder Metallurgy held in 1949. Clarifies problems in theoretical physics and powder metallurgy. Eight of the papers cover the theory of sinterwing—eight are concerned with grain structure and diffusion problems—six present experimental data on various problems of powder metallurgy. Soonsored by

various problems of powder netallurgy. Sponsored by the Metallurgical Labo-ratories, Sylvania Elec-tric Products Inc. Edited by W. F. Kingston, 404 pages, 150 illus., \$8.50



#### DIE CASTING

3 Covers the components and operations of die-casting equipment, design of die castings—construction of large dies—and the requirements, composition, and applications of both die-steels and die-casting alloys. The advantages and disadvantages of die-casting compared to other production processes are analyzed—the estimation of die-casting costs explained. By H. H. Doehler, Chairman of the Board, Doehler Jarvis Corp., 502 pages, 281 Illus., \$8.80

#### METALWORKING LUBRICANTS

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#### Increasing Bessemer Production

(Begins on p. 130)

concern is blowing time with an ample supply of hot metal; and a gradual replacement of roll scale with oxygen as the hot metal supply decreases, thus achieving the highest level of ingot production.

No pronounced effects have been found on bottoms or linings when using oxygen in the standard amounts now specified. The hotter flame keeps skulls from forming on the nose and decreases physical damage from their removal. Emphasis is placed upon the judicious use of oxygen to increase production in acid bessemer converters.

F. G. NORRIS

#### Relief of Stress in Cast Iron\*

THE EFFECTS of various annealing times and temperatures on the relaxation of stress in gray cast iron (for piston rings) are reported. The iron conformed to British Standard Specification 4K6 for aircraft materials and components and had the following analysis: Total carbon 3.37%, silicon 1.58%, manganese 0.98%, sulphur 0.095%, and phosphorus 0.78%.

Radially split rings were sprung open to a nominal gap width and maintained this way during annealing. The force necessary to maintain the constant gap width was recorded. The author reports a drop in stress during heating up to 750° F., the initial stress (whether 18,000 or 21,000 psi.) is reduced relatively little (about 15% at 750° F.) but beyond this temperature the stress is considerably reduced (about 80% at 1110° F.). Continued heating at temperature affects continued reduction in stress, although a limit to the reduction is reached eventually. At 750° F. this limit is approached at about 500 hr., at which point the initial stress is reduced about 45% at 1110° F. after 48 hr. (when the limit is approached) the reduction is about 92%. The strength of the rings was lowered by any heat treatment, about 10% at 750° F. and 15% at 1110° F.

W. M. BALDWIN, JR.

\*Abstract of "The Relief by Heat-Treatment of Externally Applied Stresses to Cast Iron", by G. N. Gilbert, Journal of Research and Development, British Cast Iron Research Association, Vol. 3, August 1950, p. 499-506



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#### Structure of Electrolytically Separated Martensite\*

In studying carbide particles that had been separated electrolytically from quenched steels, solid particles of alpha martensite were sometimes observed. This observation suggested the possibility of learning more about the processes of hardening and tempering steels by studying martensite that had been separated in this manner from the body of steel specimens.

For this purpose, carbon steels containing 0.80, 0.98, 1.16, 1.38, and 1.51% carbon were quenched from the austenite range. Aqueous solutions of hydrochloric acid or of potassium chloride and citric acid were used in electrolytically separating the martensite in these steels. X-ray diffraction patterns from the martensite residues so obtained were made using iron radiation, and comparison patterns were also made for solid specimens of the 0.98% carbon steel specimen.

Results of the electrolytic separation of the steels and the X-ray analysis of the resulting residues showed that a necessary condition for electrolytic separation of martensite is the presence of some retained austenite. The austenite has a higher solution potential than the martensite, and it is possible to cause the austenite to dissolve, thus freeing the martensite crystals.

Comparison of the diffraction patterns from the residues and from the solid steel specimen showed that the essential difference between them was the more diffuse diffraction lines in the pattern from the solid specimen. This difference was accounted for on the basis that martensite crystals in solid steel are under elastic stress, and that these stresses are largely relieved when the martensite crystals are separated from the body of the steel.

The lattice constants of the martensite were, within experimental error, the same in the solid specimen as in the residue. This fact was interpreted as showing that the tetragonality of martensite is not caused by elastic stresses in the steel, but is a natural result of the mode of crystallization of the iron and carbon atoms.

\*Abstract of "Structure of Martensite Separated Electrolytically from Quenched Steel", by M. P. Arbuzov, Doklady Akademii Nauk SSSR, Vol. 74, 1950, p. 1085-1087.

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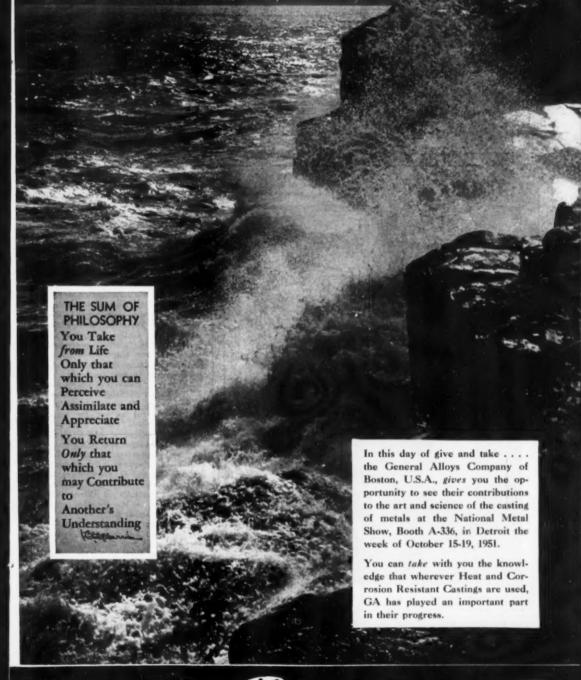
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# QALLOYS THE QUALITY NAMES IN ALLOY FOR HEAT CORROSION ABRASION



## **Turbine Materials** and Performance\*

CHIEF OBSTACLES to rapid advance of large power gas turbines for long life are: (a) cost of materials and manufacture and (b) uncertainties as to dependability over extended periods of time (100,000-hr. design goal). Several ingenious charts are provided by the authors which relate inlet operating temperatures with performance and show the penalties involved in using ferritic steels for blading and rotors as opposed to the super-austenitic alloys, such as G18B and Nimonic 80 A, currently in use. However, it is pointed out that in a complex gas turbine cycle which includes more than one stage of compression with intercooling and regeneration, higher turbine inlet temperatures cannot always be justified on the basis of better over-all performance.

The advantages of cooling the rotating blades are clearly shown in another chart. The authors demonstrate that blade root cooling, which is relatively easy to accomplish, does not, unfortunately, permit a large increase in turbine inlet temperature. Other types of cooling (such as by use of hollow blades with inserts) are much more promising but involve high manufacturing expense and operating uncertainties. Thus "sweat cooling" by use of pores distributed over the blade surface to provide a heat protecting layer of cooling air. channeled from within, would fail if the pores became clogged with impurities.

The statement is made that most large gas turbines are currently being manufactured with welded rotors, but there are many uncertainties in this method of construction. Accordingly, there is a real need for large, dependable, onepiece rotor forgings made with integral stub ends and flanges.

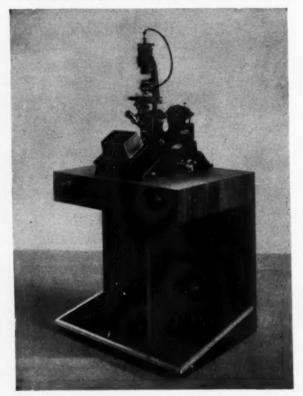
The blades are shown to be a high proportion of the cost of large gas turbines. The authors believe that the designers must accommodate their aerodynamic requirements to the use of simpler blade shapes and the metallurgists should try to provide a material which can be used in the as-rolled or as-forged condition. This may obviate the necessity for costly machining and grinding as finishing processes, which are now employed to eliminate intergranular fissures that may he produced in heat treating.

However, material problems are by no means confined to the rotating elements. There is no satisfactory material as yet for heat exchanger tubes where heat and corrosion resistance tend to work at cross purposes. Thus, aluminumbronze is attractive corrosion-wise but lacks adequate creep strength above about 900° F. The first cost is also a serious consideration, because many miles of thin-walled tubing may be incorporated in a given heat exchanger.

It is reported that a 500-hp. experimental gas turbine has run for more than 3000 hr., using either heavy oil or diesel oil for fuel. Operating temperatures have rarely exceeded 1100° F. and blade corrosion has not yet been a problem, although fouling has occurred with the use of heavy oil and the ash analyses run from about 35.0 to 62.0% vanadium as  $V_2O_5$ . C. T. Evans, Jr.

\*Abstract of "Materials and Performance", by A. T. Bowden and W. Hryniszak, Symposium on High-Temperature Steels and Alloys for Gas Turbines, Iron and Steel Institute, February 1951, p. 11-17.

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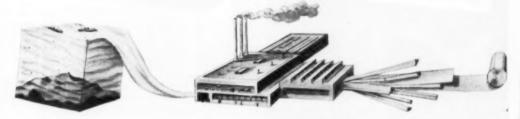
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SEPTEMBER 1951; PAGE 139



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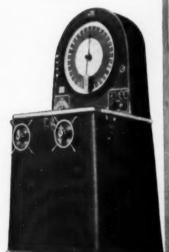
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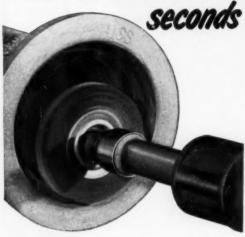


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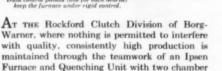
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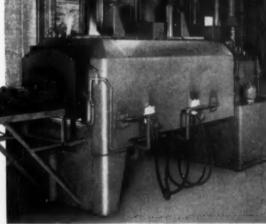


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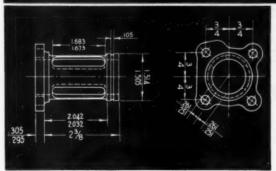
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**METAL PROGRESS; PAGE 148** 

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**METAL PROGRESS; PAGE 150** 

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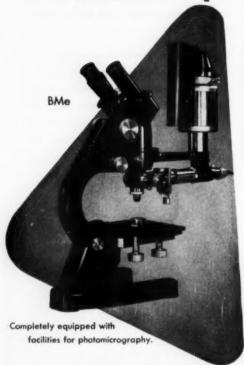
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| Driver-Harris Co                      | Minneapolis-Honeywell Regulator Co.     | Washington Steel Corp                     | 8    |
| Eastman Kodak Co. 97                  | (industrial Div.)                       |                                           |      |
|                                       | National Control Dis                    | Wheelock, Lovejoy & Co., Inc.             | 110  |
| Eberbach Corp. 142                    | National Carbon Div.,                   |                                           | 105  |
| Eclipse Fuel Engineering Co           | Union Carbide & Carbon Corp. 33         | Wisconsin Steel Co.                       | 127  |
| Electric Furnace Co Inside Back Cover | National Forge & Ordnance               |                                           |      |
| Electro Alloys Co                     | National Machinery Co                   | Youngstown Sheet & Tube Co                | 20   |
|                                       |                                         |                                           |      |

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Reply stating education, experience and personal data to Address P-77 P.O. Box 3414 Philadelphia 22, Pa.

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